FORTY-FOURTH ANNUAL REPORT

OF THE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

1958

ADMINISTRATIVE REPORT
INCLUDING TECHNICAL REPORTS

Nos. 1342 to 1392

(Final Report)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1959

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25 D.C. — Price $10.50 (Buckram)

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To the Congress of the United States:

In compliance with the provisions of the Act of March 3, 1915, as amended, which established the National Advisory Committee for Aeronautics, I transmit herewith the Forty-fourth and Final Annual Report of the Committee for the Fiscal Year 1958. This report covers the activities of the Committee through the close of business September 30, 1958, when it was superseded by the National Aeronautics and Space Administration.

The National Advisory Committee for Aeronautics is to be commended for its many contributions to the progress of aeronautical science in the United States and for the spirit of teamwork in aeronautics it has inspired among leaders in science, the military and industry. I wish also to acknowledge at this time the excellent work and dedication of the Committee's research staff who, over the years, have given unstintingly of their talents in a manner which reflects credit upon them and all other civil service personnel of the United States.

DWIGHT D. EISENHOWER.

THE WHITE HOUSE,
APRIL 27, 1959.

Letter of Submittal

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
WASHINGTON, D.C., *September 30, 1958.*

DEAR MR. PRESIDENT:

In compliance with the act of Congress approved March 3, 1915, as amended (U.S.C. title 50, sec. 151), I submit herewith the Forty-fourth Annual Report of the National Advisory Committee for Aeronautics for 1958.

At the close of business on this date the National Advisory Committee for Aeronautics goes out of existence. Under the terms of the National Aeronautics and Space Act of 1958, the property, facilities, and personnel (other than the members of the Committee) are absorbed in the establishment of the new National Aeronautics and Space Administration. This is, therefore, the concluding Annual Report of the National Advisory Committee for Aeronautics.

Respectfully submitted.

JAMES H. DOOLITTLE,
Chairman.

THE PRESIDENT,
The White House, Washington, D.C.

National Advisory Committee for Aeronautics

Headquarters, 1512 H Street NW., Washington 25, D.C.

Created by Act of Congress approved March 3, 1915, for the supervision and direction of the scientific study of the problems of flight (U.S. Code, title 50, sec. 151). Its membership was increased from 12 to 15 by act approved March 2, 1929, and to 17 by act approved May 25, 1948. The members have been appointed by the President and serve as such without compensation.

James H. Doolittle, Sc. D., Vice President, Shell Oil Co., Chairman
Leonard Carmichael, Ph. D., Secretary, Smithsonian Institution, Vice Chairman

Allen V. Astin, Ph. D., Director, National Bureau of Standards.
Preston R. Bassett, D. Sc.
Detlev W. Bronk, Ph. D., President, Rockefeller Institute for Medical Research.
Frederick C. Crawford, Sc. D., Chairman of the Board, Thompson Products, Inc.
William V. Davis, Jr., Vice Admiral, U.S. Navy (detached May 22, 1958, as Deputy Chief of Naval Operations (Air) and NACA membership terminated).
Paul D. Foote, Ph. D., Assistant Secretary of Defense (Research and Engineering).
Wellington T. Hines, Rear Admiral, U.S. Navy, Deputy and Assistant Chief of the Bureau of Aeronautics.
Jerome C. Hunsaker, Sc. D., Massachusetts Institute of Technology.
Charles J. McCarthy, S.B., Chairman of the Board, Chance Vought Aircraft, Inc.
Donald L. Putt, Lieutenant General (retired from U.S. Air Force June 30, 1958, from service as Deputy Chief of Staff, Development, and NACA membership terminated).
James T. Pyle, A.B., Administrator of Civil Aeronautics.
Francis W. Reichelderfer, Sc. D., Chief, U.S. Weather Bureau.
Edward V. Rickenbacker, Sc. D., Chairman of the Board, Eastern Air Lines, Inc.
Louis S. Rothschild, Ph. B., Under Secretary of Commerce for Transportation.
Thomas D. White, General, U.S. Air Force, Chief of Staff.

Hugh L. Dryden, Ph. D., *Director*
John W. Crowley, Jr., B.S., *Associate Director for Research*
John F. Victory, LL.D., *Executive Secretary*
Edward H. Chamberlin, *Executive Officer*

Henry J. E. Reid, D. Eng., Director, Langley Aeronautical Laboratory, Langley Field, Va.
Smith J. DeFrance, D. Eng., Director, Ames Aeronautical Laboratory, Moffett Field, Calif.
Edward R. Sharp, Sc. D., Director, Lewis Flight Propulsion Laboratory, Cleveland, Ohio
Walter C. Williams, B.S., Chief, High-Speed Flight Station, Edwards, Calif.

FORTY-FOURTH ANNUAL REPORT
National Advisory Committee for Aeronautics

WASHINGTON, D.C., *September 30, 1958.*

To the Congress of the United States:

In accordance with act of Congress, approved March 3, 1915, as amended (U.S.C., title 50, sec. 151), which established the National Advisory Committee for Aeronautics, the Committee submits its Forty-fourth Annual Report for the fiscal year 1958. This is the Committee's final report to the Congress.

The National Aeronautics and Space Act of 1958 (Public Law 85–568) provides in section 301 that the NACA "shall cease to exist" and "all functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records" of the NACA shall be transferred to the National Aeronautics and Space Administration. The aforesaid act provides that "this section shall take effect 90 days after the date of the enactment of this act, or on any earlier date on which the Administrator shall determine, and announce by proclamation published in the Federal Register, that the Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by this act." The Administrator, Hon. T. Keith Glennan, has advised the Committee of his intention to issue such proclamation, effective October 1, 1958.

During the 43 years that the NACA was charged with responsibility to "supervise and direct the scientific study of the problems of flight, with a view to their practical solution," its great strength, as reflected in the advances in aeronautics resulting from its researches, has been the high caliber of its scientists, engineers, and supporting personnel. The gratitude of the entire Nation is due these public servants.

There is another reason—subordinate only to that cited above—why the NACA was so successful in accomplishing the technological progress in aeronautics that enabled the United States to achieve and maintain superiority in the air. This was the support the Congress gave over the years, appropriating funds for construction of highly specialized laboratory facilities. These were provided for the study of new problems posed by the steady increases in aircraft performance that earlier work had made possible.

On following pages, there appear brief accounts of the history of the NACA, covering the first 40 years by Dr. J. C. Hunsaker, my predecessor as Chairman, and summarizing activities of the past 3 years, by the undersigned.

The extent of our penetration into space in the next few years will depend in large measure upon how effectively we use knowledge in hand, and upon how hard we work to reach the distant performance goals set for instrumented and man-carrying spacecraft. I know I can speak with confidence and without reservation on behalf of the 8,000 dedicated people of the NACA, who will serve as the nucleus of the National Aeronautics and Space Administration. They will continue to merit the confidence, and the support, of the President, the Congress, and the people of the United States as they perform their new and tremendously important work.

J. H. DOOLITTLE,
Chairman.

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Part I—TECHNICAL ACTIVITIES

THE NACA—WHAT IT IS AND HOW IT OPERATES

During the 43 years since the Congress founded it as an independent Federal agency, the National Advisory Committee for Aeronautics has sought to assess the current stage of development of aircraft, both civil and military; to anticipate the research needs of aeronautics; to build the scientific staff and unique research facilities required for these research needs; and to acquire the needed new knowledge as rapidly as the national interest requires.

By discharging its primary responsibility—scientific laboratory research in aeronautics—the NACA serves the needs of all departments of the Government. The President appoints the 17 unpaid members of the Committee, who report directly to him. They establish policy and plan the research to be carried out by the 7,900 scientists, engineers, and other persons who make up the staff of the agency.

The NACA research programs have both the all-inclusive, long-range objective of acquiring new scientific knowledge essential to assure United States leadership in aeronautics and space and the immediate goal of solving, as quickly as possible, the most pressing problems. In this way, they effectively support the Nation's current aircraft and missile construction program.

Most of the problems to be studied are assigned to the NACA's research centers. The Langley Aeronautical Laboratory in Virginia works on structural, general aerodynamic, and hydrodynamic problems. The Ames Aeronautical Laboratory in California concentrates on high-speed aerodynamics. The Lewis Flight Propulsion Laboratory in Ohio is a center for powerplant studies. At the High-Speed Flight Station in California special fully instrumented research aircraft probe transonic and supersonic problems in flight. The Pilotless Aircraft Research Station at Wallops Island, Va., is a branch of the Langley Laboratory where rocket-powered free-flight models are used to attack aerodynamic problems in the transonic, supersonic, and hypersonic speed ranges.

A major task of the NACA since its beginning in 1915 has been coordinating aeronautical research in the United States. Through the members of the Committee and its 27 technical subcommittees, the NACA links the military and civil government agencies concerned with flight. The aviation industry, allied industries, and scientific institutions are also represented.

Assisting the Committee in determining and coordinating research programs are 4 major and 23 subordinate technical committees with a total membership of nearly 500. Members are chosen because of technical ability, experience, and recognized leadership in a special field. They also serve without pay, in a personal and professional capacity. They furnish valuable assistance in considering problems related to their technological fields, review research in progress at NACA laboratories and in other establishments, recommend new research to be undertaken, and assist in coordinating research programs.

Members of the technical committees and subcommittees and of the Industry Consulting Committee are listed in Part II of this report, beginning on page 83.

Research coordination is also accomplished through frequent discussions by NACA scientists with the staffs of research organizations of the aircraft industry, educational and scientific institutions, and other aeronautical and space agencies. Through a west coast office the NACA maintains close liaison with aeronautical research and engineering staffs in that important aviation area.

The first report of aeronautical research published by the NACA covered a study conducted at the Massachusetts Institute of Technology under a research contract. Throughout its existence, NACA has utilized this means of obtaining the benefits of the special talents, unique facilities, and fresh points-of-view of scientists outside its own laboratories. The resulting independent thought and novel attacks upon research problems are a continuing stimulus to NACA scientists. They produce valuable data and theoretical analyses to complement internal NACA research. Fifty-two reports of sponsored research were published during the fiscal year 1958. During this period the following institutions participated in the program:

Polytechnic Institute of Brooklyn
California Institute of Technology
University of California
Georgia Institute of Technology
University of Illinois
Iowa State College
Johns Hopkins University
Lightning & Transients Research Institute
University of Maryland

Massachusetts Institute of Technology
University of Michigan
University of Minnesota
New York University
Ohio State University
Rensselaer Polytechnic Institute
Southwest Research Institute
Stanford University
Syracuse University
University of Washington

Proposals from such institutions are carefully weighed to assure best use of the limited funds available to the NACA for sponsoring research outside its own facilities. Published research reports of the useful results of this part of the NACA program are distributed as widely as other NACA publications.

Most of NACA's research information is distributed by means of its publications. Technical Notes and Reports are not classified for military security reasons and are available to the public in general. Translations of important foreign research reports appear as Technical Memorandums. The NACA also prepares research reports containing classified information. For reasons of national security, these receive carefully controlled circulation. When such information can be declassified, the research reports may be given wider distribution. Current NACA publications are announced in the NACA Research Abstracts.

Every year the NACA holds a number of technical conferences with representatives of the aviation industry, the universities, and the military services present. Attendance at these conferences is restricted because classified material is presented and the subject matter discussed at each conference is focused on a specific field of interest.

Forty Years of Aeronautical Research

By J. C. HUNSAKER
*Chairman, National Advisory Committee for Aeronautics**
Regent, Smithsonian Institution

FROM THE SMITHSONIAN REPORT
FOR 1955

Before the Wrights' airplane flew, all the elements of the airplane were known: wings, rudders, engine, and propeller. The Wrights showed how to combine a man's senses and reflexes with the controls of a flying machine to make the machine both controllable about its attitude of equilibrium and steerable as desired. The secret of flight was manual control, in a three-dimensional fluid medium, in accordance with visual signals (the pilot's view of the ground and observation of his attitude relative to it—fixed axes of references), and monitored by visual observation of the response to his control actions (feedback). The Wrights' airplane was, however, like the Wrights' bicycles, inherently unstable and was controllable only when it had sufficient forward speed. Controlled by the sight, brain, nerves, and muscles of man, the Wrights' unstable vehicle was the first practical flying machine in the history of the world!

The Wright airplane was quick to respond to control action because it had no righting tendency if disturbed. The pilot was expected to act at once to recover from any disturbance of equilibrium. There was no fixed tail to push it into a safe glide if the engine stopped.

The early pioneers of flight worked with gliders and with self-propelled models. They strove for inherent stability and conceived the ideal to be an inherently stable flying platform on which the pilot need do no more than steer. Pénaud's model gliders of the 1870's, with long tails, were stable; Lanchester developed prior to 1908 a theory of dynamical stability for his model "aerodromes"; Langley flew stable steam-powered models in 1896, and Bryan in 1903 published the dynamical equations of motion for a glider, and criteria for inherent stability. In all cases, stability was found to require a tail and slightly elevated wing-tips.

As might be expected from complete and constant dependence on one man's sometimes defective judgments and reactions, the Wright airplane could be tricky and even dangerous, especially in rough air. Furthermore, the gasoline engines of the day were notoriously unreliable. As a result of what later came to be known as the stall, Wright airplanes too often dived into the ground out of control. The press blamed it on an "air pocket" or "hole in the air."

European airplane builders were prompt to copy the Wright's system of control but soon discovered the dangers of instability. They abandoned the Wright's form of structure but retained their system of controls on airplanes shaped more like successful gliders.

The world was astonished in 1909 when Louis Bleriot flew across the English Channel in his little monoplane. It had a long tail, tractor propeller, and wheel landing gear. It was, in fact, the prototype of the airplanes of the next 20 years.

After 1910, with the mounting tension of approaching war, aeronautical development in Britain, France, Germany, Austria, Russia, and Italy was intensively pushed. Scientists, engineers, and industrialists were encouraged by their governments to devote their skills and resources to the new art. European progress was rapid, and at times spectacular.

While development of the airplane in the United States was dependent largely upon the efforts of a host of amateur inventors, there was in Europe a quick recognition of the gains to be had from aeronautical laboratories staffed by competent engineers.

The French were among the first to utilize scientific techniques in aeronuatics. The army's aeronautical laboratory at Chalais-Meudon and Gustav Eiffel's private wind tunnel clarified some of the principles of powered flight. As early as 1904 Riabouchinski had an aeronautical laboratory in Koutchino, Russia, and the same year Ludwig Prandtl began his classic aerody-

*Elected annually and served as chairman, 1941–56.

namic research at Göttingen University, Germany. After 1908, German aeronautical work was rapidly expanded, first at Göttingen and later at the government establishment at Adlershof, near Berlin. Italy provided an aerodynamics laboratory for her Specialist Brigade of Engineers.

Great Britain was relatively late in undertaking a national program of aeronautical research. However, Great Britain could record a full century of experiment. In the first half of the nineteenth century, Sir George Cayley had made important contributions, and Stringfellow and Henson had succeeded, as early as 1848, in flying a steam-powered monoplane model a distance of 120 feet. In 1866 the Aeronautical Society of Great Britain was formed; it served to stimulate research and experiment by individuals, and to provide a forum for interchange of information. Wenham (the Society's first president) and Phillips were the first to devise and use wind tunnels.

After the public demonstration of practical human flight by Wilbur Wright on his 1908 visit to France and Bleriot's 1909 cross-channel flight, the British Prime Minister was moved to appoint an Advisory Committee for Aeronautics with the great physicist Lord Rayleigh as chairman.

During the same period the United States made no special effort. The Army Signal Corps bought a few airplanes to train pilots and the Navy set up a flying school equipped with Glenn Curtiss seaplanes. When World War I erupted in 1914 it was reported that France had 1,400 airplanes, Germany 1,000, Russia 800, Great Britain, 400, and the United States 23!

DRIVE FOR A NATIONAL LABORATORY

The backward position of the United States in the application of applied science to this new art was realized by a growing list of prominent Americans who believed the situation was not only a national disgrace, but a possible danger to our security. More Americans, including the leaders in Congress, were strong for neutrality, and felt that any special government concern with aeronautical development might imply belligerent intentions.

Capt. W. I. Chambers, USN, officer-in-charge of naval-aviation experiments, proposed in 1911 that a national aeronautical research laboratory be set up under the Smithsonian Institution. Along with objections by both the War and Navy Departments, the plan was referred to President Taft's Committee on Economy and Efficiency, from which it was never returned.

Two men who were more influential in the drive for a national aeronautical laboratory were Alexander Graham Bell and Charles Doolittle Walcott. The former, as a regent of the Smithsonian Institution, had been a supporter of Langley and had experimented with the lifting capabilities of kites. With Mrs. Bell he formed the Aerial Experiment Association in 1907 to support the airplane experiments of Glenn Curtiss, Lt. T. E. Selfridge, F. W. ("Casey") Baldwin, and J. A. D. McCurdy. Their efforts resulted in the development of the Curtiss biplanes and the use of ailerons to replace the Wright's wing warping for lateral control.

Dr. Walcott was no aeronautical scientist; his field was geology. But Dr. Walcott, as successor to Professor Langley as Secretary of the Smithsonian, was determined that the Institution should resume its position as a leader of aeronautical science in America. How better than to have the new aeronautical laboratory attached to the Smithsonian!

The establishment of a national aeronautical laboratory was pressed by members of the National Academy of Sciences, notably by Bell and Walcott. The Academy had been created by Congress during the Civil War and had the duty of giving advice to the Government, when asked. The Academy, as a body, was not asked for advice on this matter, but its members appear to have been influential in persuading President Taft to appoint on December 19, 1912, a 19-man commission to consider such a national laboratory and its scope, organization, and cost, and to make a recommendation to the Congress.

The President's Commission was headed by Dr. R. S. Woodward of the National Academy of Sciences and the Carnegie Institution of Washington and included Dr. Walcott. The Army, Navy, Weather Bureau, and Bureau of Standards were represented, as well as interested civilians. The Commission recommended that the laboratory be established in Washington and administered by the regents of the Smithsonian Institution. President Maclaurin of the Massachusetts Institute of Technology objected to the location at Washington, which the majority report favored as "conveniently accessible to statesmen of the National Government who may wish to witness aeroplane demonstrations."

Unfortunately, the President had appointed the Commission without "the advice and consent of the Senate." Authorizing legislation failed to get unanimous consent and the Commission's report was buried in the archives.

Probably as a result of his service with the President's Commission, President Maclaurin in May 1913 persuaded the Corporation of M.I.T. to authorize a graduate course in aeronautical engineering and a wind tunnel for aerodynamic research in the Department of Naval Architecture. He requested the Secretary of the Navy to detail an officer of the Construction Corps to take charge. The writer was so detailed for 3 years.

At about the same time, the Smithsonian regents decided to reopen Langley's old laboratory, with Dr. Albert F. Zahm in charge. It was arranged by Walcott and Maclaurin to send Zahm and Hunsaker abroad, armed with personal introductions to scientific friends. Their objective was to visit the principal aeronautical research laboratories and, as far as possible, to learn how to operate the special facilities and equipment in use there with a view to duplicating them in this country.

Visits were made to the Royal Aircraft Factory, the National Physical Laboratory, and Cambridge University in England; to the St. Cyr, Chalais-Meudon, and Eiffel Laboratories in France; and to the Deutsche Versuchsanstalt für Luftfahrt and Göttingen University in Germany. In 1913, security restrictions did not apply to scientific and engineering work and the visitors were cordially received. In fact, the Massachusetts Institute of Technology later built its wind tunnel from drawings supplied by Sr. Richard Glazebrook of the NPL and the NPL aerodynamic balances duplicated by Sir Horace Darwin's Cambridge scientific instrument shops.

Dr. Zahm's report, published by the Smithsonian in 1914, made clear the width of the gap between European and American positions in aeronautical science. This report had an important influence on the decision of the Smithsonian regents in 1915 to memorialize the Congress once again on the subject of a national aeronautical laboratory.

Woodrow Wilson approved the Smithsonian plan of reopening Langley's laboratory with representatives of the War, Navy, Agriculture, and Commerce Departments serving on an Advisory Committee. However, the Comptroller ruled that, under an act of 1909, such an Advisory Committee could not serve without the authority of the Congress.

On December 10, 1914, the Chancellor of the Smithsonian, Chief Justice White, appointed Dr. Alexander Graham Bell; Senator William J. Stone of Missouri; Representative Ernest W. Roberts of Massachusetts, and John B. Henderson, Jr., regents; and Dr. Walcott, Secretary, to consider once again "questions relative to the Langley Aerodynamical Laboratory." On February 1, 1915, a "memorial on the need for a National Advisory Committee for Aeronautics" was delivered to the Speaker of the House. Pertinent sentences from the memorial follow:

> This country led in the early development of heavier-than-air machines. Today it is far behind. . . . A National Advisory Committee for Aeronautics cannot fail to be of inestimable service in the development of the art of aviation in America. Such a committee, to be effective, should be permanent and attract to its membership the most highly trained men in the art of aviation. . . . Through the agency of subcommittees, the main advisory committee could avail itself of the advice and suggestions of a large number of technical and practical men. . . . The aeronautical committee should advise in relation to the work of the Government in aeronautics and the coordination of the activities of governmental and private laboratories, in which questions concerned with the study of the problems of aeronautics can be experimentally investigated.

The Navy heartily endorsed the idea in a letter dated February 12 and signed by Franklin D. Roosevelt as Acting Secretary.

ESTABLISHMENT OF NACA

The joint resolution establishing the Advisory Committee and authorizing the President to appoint its 12 members was given final form in February. The people of the United States were at the time generally anxious to avoid involvement in what was then called the War in Europe. President Wilson is said to have felt that the establishment of a new aeronautical enterprise might reflect on American neutrality. Such reasoning may explain why the resolution was attached to the naval appropriation bill; perhaps a more likely reason was that in the rush to clear the legislative "logjam" by March 4, the date for adjournment of the Congress, Representative Roberts, Smithsonian regent, had found it simpler to effect its adoption by introducing the measure, as a rider to the naval appropriation bill, in the Committee on Naval Affairs, of which he was a member.

Following is the provision in the Naval Appropriations Act, approved March 3, 1915:

> An Advisory Committee for Aeronautics is hereby established, and the President is authorized to appoint not to exceed twelve members, to consist of two members from the War Department, from the office in charge of military aeronautics; two members from the Navy Department, from the office in charge of naval aeronautics; a representative each of the Smithsonian Institution, of the United States Weather Bureau, and of the United States Bureau of Standards; together with not more than five additional persons who shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences: *Provided*, That the members of the Advisory Committee for Aeronautics, as such, shall serve without compensation: *Provided further*, That it shall be the duty of the Advisory Committee for Aeronautics to supervise and direct *the scientific study of the problems of flight, with a view to their practical solution, and to determine the problems*[1] which should be experimentally attacked, *and to discuss their solution and their application to practical questions*. In the event of a laboratory or laboratories, either in whole or in part, being placed under the direction of the committee, the committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories: *And provided further*, That rules and regulations for the conduct of the work of the committee shall be formulated by the committee and approved by the President.
>
> That the sum of $5,000 a year, or so much thereof as may be necessary, for five years is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be immediately available, for experimental work and investigations undertaken by the committee, clerical expenses and supplies, and necessary expenses of members of the committee in going to, returning from, and while attending meetings of the committee:

[1] Italics in this and the following quotation supplied by the author for emphasis.

Provided, That an annual report to the Congress shall be submitted through the President, including an itemized statement of expenditures.

This language establishing the NACA closely followed that used by the British Prime Minister when he announced the formation of a similar committee to the House of Commons on May 5, 1909, in the following words:

It is no part of the general duty of the Advisory Committee for Aeronautics either to construct or to invent. Its function is not to initiate but to consider what is initiated elsewhere, and is referred to it by the executive offices of the Navy and Army construction departments. The problems which are likely to arise in this way for solution are numerous, and it will be the work of the committee to advise on these problems and to seek their solution by the application of both theoretical and experimental methods of research.

The work desired thus falls into three sections: (1) *The scientific study of the problems of flight, with a view to their practical solution.* (2) Research and experiment into these subjects in a properly equipped laboratory with a trained staff. (3) The construction and use of dirigibles and aeroplanes, having regard mainly to their employment in war.

The Advisory Committee are to deal with the first section, and also *to determine the problems* which the experimental branch should attack, *and discuss their solutions and their application to practical questions.* The second section represents the work referred to the laboratory (the National Physical Laboratory), while the duties concerned with the third section remain with the Admiralty and the War Office.

On April 2, 1915, President Woodrow Wilson appointed to the new Committee: Prof. Joseph S. Ames, of the Physics Department of Johns Hopkins University; Capt. Mark L. Bristol, USN, Director of Naval Aeronautics, Navy Department; Prof. William F. Durand, of the Engineering Department of Leland Stanford University; Prof. John F. Hayford of the Engineering Department of Northwestern University; Dr. Charles F. Marvin, Chief of the U.S. Weather Bureau; Hon. Byron R. Newton, Assistant Secretary of the Treasury; Prof. Michael I. Pupin of the Physics Department of Columbia University; Lt. Col. Samuel Reber, USA, Officer-in-Charge, Aviation Section of the Signal Corps, War Department; Naval Constructor Holden C. Richardson, USN, Department of Construction and Repair, Washington Navy Yard; Brig. Gen. George P. Scriven, USA, Chief Signal Officer, War Department; Dr. Samuel W. Stratton, Director, National Bureau of Standards; and Dr. Charles D. Walcott, Secretary, Smithsonian Institution.

Of the initial 12 members, 6 were members of the National Academy of Sciences (within the period of their NACA membership). It is of interest to note that for 40 years all chairmen of the NACA except the first, General Scriven, have been members of the National Academy. In 1955, there are 5 Academy members out of 17 members of the NACA. This statistic is of significance in view of the increasing impact on aeronautics of advances in many fields of science: for example, physiology and psychology of pilots, chemistry of combustion, physics of metals, physics of the atmosphere, acoustics, communications, electronics. The Committee is strengthened by the special knowledge of its individual members.

By direction of the President, the Secretary of War called the first meeting. The date was April 23, 1915; the place, his office. Conforming with the designation in the call for the first meeting, the word "National" was prefixed to the title "Advisory Committee for Aeronautics." General Scriven was elected temporary chairman, and Naval Constructor Richardson temporary secretary. With formulation of rules and regulations, subsequently approved by the President, the temporary chairman and secretary were elected for one year.

Perhaps the most important regulation adopted was for an executive committee, composed of 7 of the 12 members of the Advisory Committee. The full Committee was to meet only semiannually. The executive committee was set up to meet regularly throughout the year and was charged with the administration of the affairs of the Committee and "general supervision of all arrangements for research."

Dr. Walcott was the first chairman of the executive committee. The other members were Dr. Ames, Captain Bristol, Dr. Marvin, Dr. Pupin, Colonel Reber, and Dr. Stratton, with Naval Constructor Richardson, ex officio, as secretary. Improvised quarters in the Army's Aviation Section were used the first year.

In the beginning the executive committee was a working group; the NACA had no paid personnel. It was not until June 23 that the first employee was hired. He was John F. Victory; 41 years later he is continuing his faithful, effective service to the Committee. In 1917 he was named assistant secretary of the Committee; 10 years later he became secretary, and in 1945, executive secretary.

One of the first problems was to examine what aeronautical research was then in progress in the United States—both under Government auspices and by private organizations—and then to effect rational coordination to assure maximum value from the total effort. Congressman Roberts, reporting on the need for the NACA on February 19, 1915, had well stated the situation:

Besides these governmental agencies [he named the Bureau of Standards, the Weather Bureau and the War and Navy Departments] for the development of aviation, individuals in civil life have devoted time and expense in the scientific study and practical development of aeronautics. At the present time all of these agencies, both governmental and private, work independently without any coordination of activities.

Ten years later Dr. Ames gave a prime reason for "the great success of the Committee, because the Committee is a success," the coordination, on a rational scale, of American aeronautical research. His comments were made before hearings of the President's Aircraft Board (often called the Morrow Board). He spoke as chairman of the executive committee, to which position he had been elected when Dr. Walcott became Committee chairman in 1919.

In part, Dr. Ames said:

> The organization has an Executive Committee which appoints a number of technical subcommittees whose function it is to coordinate the research work throughout the country. . . . The various problems which all the services of the Government and the people engaged in industry, so far as we know, have in mind are brought before these subcommittees. The importance of each problem is discussed, and a program is laid out. . . .
>
> Around our table meet . . . representatives from all the Government services involved. . . . We work for all the departments of the Government.
>
> Furthermore, there are discussions going on at our table between the Army and the Navy and all other people interested which otherwise would not take place. We are really a coordinating body and that function would be impossible if our organization were to be transferred to any executive department as such, because if our Committee were to be a part of any department it would necessarily follow that the aeronautical needs of that department would be primarily served. . . .
>
> We think, therefore, that in our independent existence we offer a wonderful opportunity for serving all the departments.

In 1915 one of the first projects undertaken by the executive committee was a survey of facilities available "for the carrying on of aeronautic investigations." It was determined that "a number of institutions have available mechanical laboratories and engineering courses capable of application to aeronautics, but only the Massachusetts Institute of Technology and the University of Michigan so far offer regular courses of instruction and experimentation." Note was made of the experiments with full-scale propellers mounted on a whirling table, being conducted at Worcester Polytechnic Institute.

"It appears that the interest of colleges is more one of curiosity than that of considering the problem as a true engineering one, requiring development of engineering resources and, therefore, as not yet of sufficient importance to engage their serious attention," the NACA commented in its first annual report. "Manufacturers are principally interested in the development of types which will meet Government requirements or popular demand, but which will not involve too radical or sudden changes from their assumed standard types."

The Committee recognized that "considerable work had already been accomplished with which the general public is not acquainted." The annual report said of this point: "This covers lines of development and investigation which if published would save money and effort on the part of individual investigators and inventors who are now duplicating investigations already made by others. . . . Some of this information is already embodied in reports which are only accessible to a few interested parties who know of its existence."

The Smithsonian Institution had published a bibliography of aeronautics, covering the period through the middle of 1909. Now the NACA undertook publication of later bibliographies compiled by Paul Brockett of the Smithsonian. The first such volume covered the period 1909–16; as soon as past years had been "caught up," the bibliography was published annually into the early thirties.

The Committee was fully aware that to fulfill its obligations would require not only a well-equipped, suitably staffed laboratory, but also a flight test center where engineers could determine "the forces acting on full-sized machines." It was felt, however, that "since the equipment of such a laboratory as could be laid down at this time might well prove unsuited to the needs of the early future, it is believed that such provision should be the result of gradual development."

In October 1916 the Committee recommended that the War Department (which alone had funds available) purchase land about 4 miles north of Hampton, Va., for use by the Army and Navy as an aircraft proving ground. Named Langley Field, this site became the home of NACA's first research center. The War Department used it for pilot training during World War I. Aircraft development work of both the Army and Navy was centered elsewhere.

Lacking its own facilities, the NACA took prompt steps to contract for research to be performed for it by others. The first annual report included seven reports, as follows:

No. 1. Report on behavior of aeroplanes in gusts, by the Massachusetts Institute of Technology.
- Part 1. Experimental analysis of inherent longitudinal stability for a typical biplane, by J. C. Hunsaker.
- Part 2. Theory of an aeroplane encountering gusts, by E. B. Wilson.

No. 2. Investigation of pitot tubes, by the United States Bureau of Standards.
- Part 1. The pitot tube and other anemometers for aeroplanes, by W. H. Herschel.
- Part 2. The theory of the pitot and venturi tubes, by E. Buckingham.

No. 3. Report on investigations of aviation wires and cables, their fastenings and terminal connections, by John A. Roebling's Sons Co.

No. 4. Preliminary report on the problem of the atmosphere in relation to aeronautics, by Prof. Charles F. Marvin.

No. 5. Relative worth of improvements on fabrics, by the Goodyear Tire & Rubber Co.

No. 6. Investigations of balloon and aeroplane fabrics, by the United States Rubber Co.
- Part 1. Balloon and aeroplane fabrics, by Willis A. Gibbons and Omar H. Smith.
- Part 2. Skin friction of various surfaces in air, by Willis A. Gibbons.

No. 7. Thermodynamic efficiency of present types of internal-combustion engines for aircraft, by Columbia University.
- Part 1. Review of the development of engines suitable for aeronautic service, by Charles E. Lucke.
- Part 2. Aero engines analyzed with reference to elements of process or function, by Charles E. Lucke.

"What has already been accomplished by the Committee has shown that although its members have devoted as much personal attention as practicable to its operations, yet in order to do all that should be done technical assistance should be provided which can be continuously employed," the Committee said in its first Annual Report.

For the fiscal year 1917 the NACA asked for and received $85,000. Of the funds available, $68,957.35 (all that was not spent otherwise) went toward construction of the new laboratory at Langley Field. Its total cost was estimated at $80,000, a figure that later was revised upward.

The war was over before the "Committee's field station" at Langley Field could be said to be in useful operation. The annual report for 1919 noted that the Committee's first wind tunnel, with a 5-foot test section, was completed but inoperative for lack of power. The Army's power plant at Langley Field was incomplete, with construction stopped for lack of money.

With the Army planning to keep its experimental work in aeronautics at McCook Field, Dayton, and with the Navy's experimental aviation work centered at Norfolk, the NACA in 1919 felt it had good reasons for moving its field station activities to Bolling Field, just across the Anacostia River from the Capital. It asked Congress to authorize the move:

> The Committee believes it uneconomical and unsatisfactory to remain at Langley Field. The same work can be carried on more efficiently, more promptly, and more economically at Bolling Field, where the work can be closely watched by all members of the Committee, and where the members of the engineering staff in charge of work can have ready access to the Committee, to large libraries, and other sources of information, constant communication with the Bureau of Standards, a more satisfactory market for labor and supplies and adequate power supply, and relief from the perplexing question of securing quarters at Langley Field or in Hampton or other nearby towns.

Congressional approval for the move to Bolling Field did not come. In April 1920, the Committee, perhaps with a collective sigh, took action that accepted as permanent the Langley Field site for the "field station." It sought Presidential approval of the name, "Langley Memorial Aeronautical Laboratory." President Wilson concurred, and dedicatory exercises were conducted on June 11. Attendance included guests, it was later reported, "of whom a number had flown to the field."

This date, June 11, 1920, may be considered the real beginning of NACA's own program of aeronautical research, conducted by its own staff in its own facilities. The previous year a start had been made in obtaining full-scale performance data from flight tests, but now the availability of a wind tunnel made possible systematic investigations of critical aerodynamic problems, such as: (1) Comparison between the stability of airplanes as determined from full-flight test and as determined from calculations based on wind-tunnel measurements; (2) comparison between the performance of full-scale airplanes and the calculations based on wind-tunnel experiments, and (3) airfoils, including control surfaces, with special attention to thick sections, plus combinations and modification of such sections.

THE COMMITTEE'S ADVISORY FUNCTIONS

This has been essentially a chronological account, first, of events preceding establishment of the NACA, and then its early steps to undertake its responsibilities as the nation's aeronautical research establishment. At this point it is in order to glance briefly at some early activities of the Committee which were consonant with the "Advisory" in its name.

In 1916 the executive committee invited engine manufacturers to attend a meeting on June 8 in Dr. Walcott's office at the Smithsonian Institution to discuss the problem of obtaining more powerful and more reliable engines and to bring about a better understanding between builders and users. Representatives of the military services were in attendance, and although it is to be doubted that many problems were solved, unquestionable good was done by bringing them into sharp focus. Another benefit from the meeting was an arrangement whereby the Society of Automotive Engineers became active in providing assistance in the solution of aircraft powerplant problems.

Also in 1916 the Committee examined the problem of the carriage of mail by air. The Post Office Department had failed in efforts to establish a contract airmail service in Alaska and from New Bedford to Nantucket Island. Airmail was then considered to be justified only over almost impossible terrain. "Conditions of both these routes were so severe as to deter responsible bidders from undertaking this service," the Committee decided. It felt, nonetheless, that because of the great progress made in aviation, the Post Office should set up one or more experimental routes, "with a view to determining the accuracy, frequency, and rapidity of transportation which may reasonably be expected under normal and favorable conditions, and therefrom to determine the desirability of extending this service wherever the conditions are such as to warrant its employment."

The above-stated opinion was transmitted to Congress in 1916 as a recommendation. In 1918, when $100,000 was appropriated for creation of an experimental airmail service, the NACA invited the attention of the Secretary of War to the following facts: "Practically all aircraft manufacturing facilities in the United States were being utilized by the War and Navy Departments, and all capable aviators were in the military or naval air services . . . [and] it was exceedingly desirable that Army aviators be regularly and systematically trained in long-distance flying . . . [and that] it would appear to be to the advantage of the War Department and of the Government generally that military airplanes be used to render practical and effective service" in carrying mail between Washington, Philadelphia, and New York. In its 1918 annual report the NACA viewed with satisfaction the manner in which the experimental airmail service had been established along the lines recommended, and expressed the opinion it had already "been sufficiently well demonstrated since its inauguration to justify its extension generally."

In 1921, the Committee noted in a special report to the President that—

There are several causes which are delaying the development of civil aviation, such as the lack of airways, landing fields, aerological service, and aircraft properly designed for commercial uses. The Air Mail Service stands out as a pioneer agency, overcoming these handicaps and blazing the way, so to speak, for the practical development of commercial aviation. As a permanent proposition, however, the Post Office Department, as its functions are now conceived, should no more operate directly a special airmail service than it should operate a special railroad mail service; but until such time as the necessary aids to commercial aviation have been established it will be next to impossible for any private corporation to operate under contract an airmail service in competition with the railroads.

In January 1917, the War and Navy Departments complained to the NACA about prohibitive prices for aircraft, said to be due to "the extra item of royalty added by each firm in anticipation of infringement suits by owners of alleged basic aeronautic patents who were then threatening all other airplane and seaplane manufacturers with such suits, and causing thereby a general demoralization of the entire industry."

The Committee held meetings with Government officials, owners of patents, and aircraft manufacturers. It then recommended organization of a Manufacturers Aircraft Association to effect the cross licensing of aeronautic patents and to make the use of all such patents available to any member firm at the relatively small cost of $200 per airplane. This happy solution was adopted, and resulted, in the Committee's opinion, in "the prevention of the virtual deadlock with danger of monopoly existing under the patent situation."

In many other ways the Committee gave advisory service on such varied matters as provision of insurance for aviators, naming of flying fields "in commemoration of individuals who had rendered conspicuous service," aerial mapping techniques, and selection of a site near Washington for a "landing field" to provide "accommodation of transient aviators."

A special subcommittee during World War I examined some 7,000 inventions and suggestions in the field of aeronautics. Of this work the NACA later said, "The great majority of the suggestions received are obviously of an impractical nature. Several, however, have seemed worthy of further consideration and have been referred to military or naval experts." In addition to this arduous task, the Committee served as arbitrator in the settlement of disputes involving technical questions between private parties and the military services.

Perhaps the most important of NACA's advisory services was the leadership which the Committee gave to the efforts for legislation necessary to the orderly development of civil aviation. With cessation of hostilities in 1918, the Committee promptly took up the basic question of what should be done about the civil use of aircraft. Although it would be nearly 8 years before the required Federal legislation was adopted (the Air Commerce Act of 1926), the recommendations made by the Committee in 1918 encompassed what was needed: "Federal legislation . . . governing the navigation of aircraft in the United States and including the licensing of pilots, inspection of machines, uses of landing fields, etc. . . . designed to . . . encourage the development of aviation . . . and at the same time to guide the development . . . along such lines as will render immediate and effective military service to the Nation in time of war."

On April 1, 1921, President Harding directed the Committee to meet with representatives of interested Government departments to determine what could be done to achieve Federal regulation of air navigation without legislative action, and what new legislation was needed. April 9, the recommendations were formulated. The Committee was brief: "Federal regulation of air navigation cannot be accomplished under existing laws. . . . It is recommended that a Bureau of Aeronautics be established in the Department of Commerce."

There were other NACA proposals in 1921: That the Post Office be authorized to extend its airmail routes across the continent, and that naval aviation activities be centered in a Bureau of Aeronautics within the Navy Department.

In its Annual Report for 1921, the NACA noted the principal reason for delay in passing the recommended legislation:

The Committee is not unmindful of the legal sentiment that a constitutional amendment should first be adopted before such legislation is enacted, on the ground that effective regulation of air navigation as proposed would otherwise be unconstitutional as violating the rights of property and encroaching upon the rights of States. To postpone such legislation until a constitutional amendment can be proposed and ratified would have the effect of greatly retarding the development of commercial aviation, with no assurance that sufficient popular interest would ever be aroused to accomplish such an amendment. The Committee is of the opinion that the most effective course to be followed for the development of aviation would be first to enact the legislation deemed necessary for the Federal regulation of air navigation and the encouragement of the development of civil aviation, and let the question of the constitutionality of such legislation be tested in due course. In the meantime, there would be development in civil and commercial aviation, and if eventually the legislation which made possible such development should be definitely determined to be unconstitutional there would then, in all probability, be sufficient public interest in the subject and popular demand to adopt an amendment to the Constitution.

Years of perseverance culminated, in April 1926, in a careful analysis by the Committee of fundamental differences of opinion respecting certain aspects of the basic legislation then before the Congress. The solutions then proposed by the NACA were accepted by the joint Senate-House conferees, and the Air Commerce Act became law on May 20, 1926.

"This act provides the legislative cornerstone for the development of commercial aviation in America," the Committee said. It "gives an important measure of stability to commercial aviation as a business proposition and in its direct effects will go far toward encouraging the development of civil and commercial aviation."

AERONAUTICAL RESEARCH

The Air Commerce Act made the Secretary of Commerce responsible for the regulation of civil aviation, and for its encouragement. At the same time, this action freed the NACA from an "advisory" burden it had carried during its first 10 years. From now on, the Committee could concentrate upon its chief responsibility—the conduct of aeronautical research.

During the first 10 years of the Committee's existence demands upon the time of NACA members were very heavy. From 1915 to 1919 the Committee had three chairmen: General Scriven, 1915; Dr. Durand, 1916–18, and Dr. John R. Freeman, 1919. Dr. Freeman was sent on a mission to China and was succeeded as chairman in 1919 by Dr. Walcott, who had served as chairman of the executive committee since its formation in 1915.

Dr. Walcott was succeeded as chairman of the executive committee by Dr. Ames, who effectively supported Dr. Walcott until the latter's death in 1927. At that time Dr. Ames became chairman to serve until his retirement in 1939. The fact that he was located in Baltimore, where he headed the physics department of Johns Hopkins University until he became president of the University in 1929, proved no handicap. Dr. Ames was in Washington as often and as long as Committee business required.

With the development of laboratory facilities at Langley, the NACA began building a competent engineering staff. The Langley Laboratory attracted young men with good training, who could grow to do work of increasing importance. The independence of the NACA was one of the attractions, as was also the opportunity for the young engineer to sign the published report of his own research. So was the availability of superior research and test equipment.

In 1919 the Committee invited Dr. George W. Lewis, professor of mechanical engineering at Swarthmore College, to become its executive officer. In this capacity, he was called upon to guide the research programs and to plan and build the research tools needed. In 1924 Dr. Lewis' title was changed to one that more closely described his responsibilities, director of aeronautical research. From then until 1945, when his health failed under the tremendous burdens he insisted upon carrying during World War II, George Lewis gave devoted and effective leadership to the staff of the Committee.

While the Committee was acquiring the equipment at Langley necessary for the research programs envisioned, use was made of facilities available elsewhere for certain investigations. Before the end of World War I, Dr. Durand was conducting most valuable research on air propellers at Leland Stanford University, and at MIT the availability of a wind tunnel and staff made possible fundamental aerodynamic research on stability and control and on the characteristics of wing sections.

The National Bureau of Standards worked on aeronautical problems at the request of the NACA and with its financial support. The Bureau developed apparatus for the study of combustion problems under simulated conditions of high altitude and later equipped itself with wind tunnels for fundamental research on turbulence and boundary-layer problems.

The aeronautical experimentation carried on at the Navy Yard in Washington and at McCook Field in Dayton was correlated with a comprehensive plan which the NACA formulated and which was kept up to date as military and industry needs changed. The pioneering work by Naval Constructor Richardson on seaplane hulls, and the later researches directed by Chief Constructor David W. Taylor, contributed significantly to the advancement of naval aviation. At McCook Field (later moved and enlarged to become Wright Field) the availability of a wind tunnel caused the NACA to detail one of its first technical employees, Dr. George de Bothezat (best known, perhaps, for his later work with helicopters) to Dayton to assist with aeronautical research there.

In 1920 the NACA's first wind tunnel was put to work. With relatively minor exceptions, this first major piece of equipment was patterned after one at the British National Physical Laboratory. The work that could be done with this tunnel was essentially no different from that which could be accomplished at the Navy Yard, McCook Field, MIT, or other locations where conventional wind tunnels were located.

In June 1921, the executive committee decided to build a new kind of wind tunnel. Utilizing compressed air, it would allow for "scale effects" in aerodynamic model experiments. This tunnel represented the first bold step by the NACA to provide its research personnel with the novel, often complicated, and usually expensive equipment necessary to press forward the frontiers of aeronautical science. It was designed by Dr. Max Munk, formerly of Göttingen.

The value of the new tunnel was explained in 1922 by Dr. Ames:

> When a new design of airplane . . . is made, it is customary to construct a model of it, one-twentieth the size or less, and to experiment upon this. The method now in universal use is to suspend the model from suitable balances in a stream of air . . . at a velocity of 60 mph. . . . The balances register the forces and moments acting on the model. From the results of such measurements one decides whether the original design is good or not. But is one justified in making such a decision? Why should the same laws apply to a little model inside the wind tunnel, as it is called, and to the actual airplane flying freely through the air? Evidently there is ground for grave uncertainty. The Committee has perfected a method for obviating this. It has been known from aerodynamic theory for some time that the change in scale, from airplane to its model, could be compensated by compressing the air from ordinary pressure to 20 or 25 atmospheres: as the structure moving through the air is reduced in size from 50 feet to 2 feet, the molecules of the air are brought, by comparison, closer and closer together until their distance apart is one twenty-fifth of what it was originally. The effect of scale is thus fully compensated and experiments upon a model in this compressed air have a real meaning. The Committee has constructed a large steel tank, 34 feet long and 15 feet in diameter, inside which is placed a wind tunnel with its balances, etc., and in which the air may be kept in a state of high compression. The information to be obtained from the apparatus will be the most important ever given airplane designers.

Experience with simple airplane models without propellers in the variable-density tunnel encouraged the NACA, in June 1925, to construct a wind tunnel large enough to test full-scale airplane propellers under conditions of flight. This was a costly decision, but the cost was repaid manyfold by improved airplane performance.

The propeller research tunnel was put into operation in 1927. It had a circular test section 20 feet in diameter and was powered by two Diesel engines rated at 1,000 hp. each. Its air speed was 110 mph. and, at the time, it was the largest wind tunnel in the world. Almost from the beginning of its use, the PRT provided information leading to design changes which resulted in dramatic improvements in airplane performance.

The first and most spectacular of these productive researches brought about the development of what became known as the NACA cowling for air-cooled radial engines. In its 1928 report, the Committee said that "by the application of the results of this study to a Curtiss AT–5A Army pursuit training plane, the maximum speed was increased from 118 to 137 mph. This is equivalent to providing approximately 83 additional horsepower without additional weight or cost of engine, fuel consumption, or weight of structure. This single contribution will repay the cost of the Propeller Research Tunnel many times."

The Collier Trophy, awarded annually "for the greatest achievement in aviation in America, the value of which has been thoroughly demonstrated by actual use during the preceding year," went to the NACA for the development of this form of cowling. President Hoover made the presentation on January 3, 1930 (for the year 1928), and after the reading of the citation Dr. Ames responded that "a scientist receives his reward from his own work in believing that he has added to human knowledge; but he is always gratified when his work is recognized as good by those competent to judge."

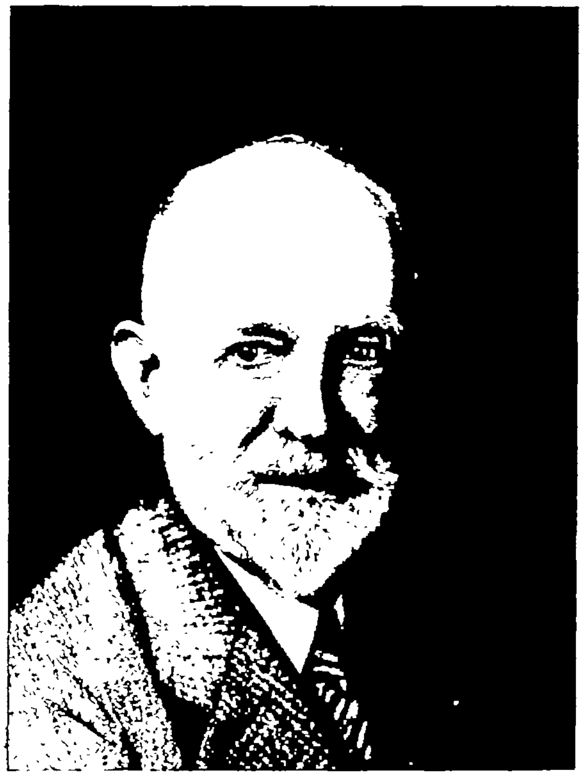
A second important benefit accruing from work in the PRT was more positive information about the best location of engine nacelles. The engines of the Ford Tri-motor, and similar aircraft of the twenties, were hung below the wing. As a consequence of research reported confidentially in 1930, multiengine aircraft designed thereafter had their engines faired into the leading edge of the wing with an important gain in speed.

The systematic work accomplished in the PRT led to other practical design changes. For example, it was possible to obtain an accurate estimate of the drag caused by such apparently insignificant details as the location of a gasoline filler cap. Similarly, engineers studied the aerodynamic interference of wings and fuselage, and the use of fillets to reduce the interference was proposed. (In 1928 the NACA published its first Technical Note on this subject, by Melvin N. Gough.)

That the fixed landing gear represented a large amount of drag had long been appreciated, but it was not until the PRT became operative that the drag penalties of fixed landing gear could be determined precisely. The higher speeds made possible by use of the NACA cowling, the wing positioning of the engine nacelles, the filleting of wing-fuselage junctures, and other aerodynamic refinements now made attractive the investment of added cost and weight implicit in retractable landing gear.

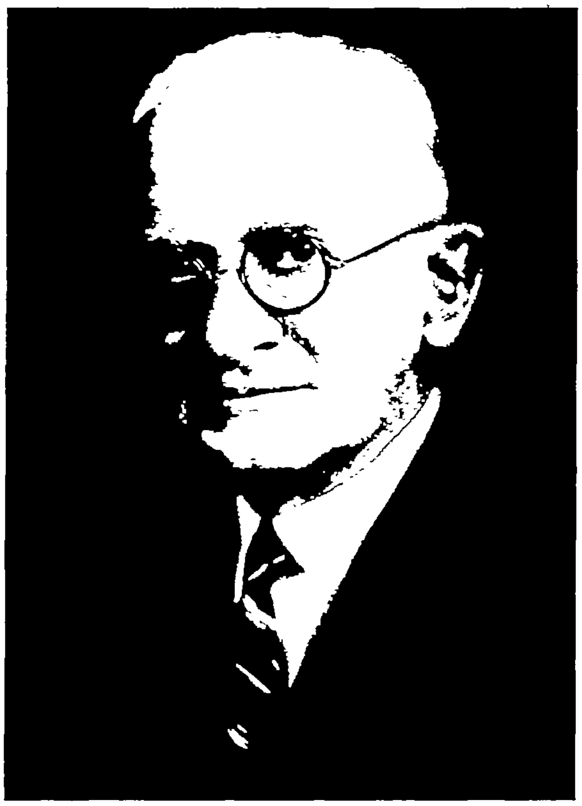
In 1933, looking at the gains from the research at its Langley Laboratory, the Committee said: "No money estimate can be placed on the value of superior performance of aircraft in warfare . . . nor can a money estimate be placed on . . . improved safety. . . . The value in dollars and cents of improved efficiency in aircraft resulting from the Committee's work can, however, be fairly estimated. For example, the results of . . . researches completed by the Committee within the last few years, show that savings in money alone will be made possible in excess annually of the total appropriations for the Committee since its establishment in 1915."

The economic depression that began with the stock-market crash of 1929 was not an unmixed evil for the NACA. Although there were strong pressures to re-



Dr. William F. Durand, member National Advisory Committee for Aeronautics 1915–33, 1941–45; Chairman, 1916–18.

Dr. Charles Doolittle Walcott, Secretary Smithsonian Institution 1907–27; member National Advisory Committee for Aeronautics 1915–27; Chairman, Executive Committee, 1915–19; Chairman, 1919–27.



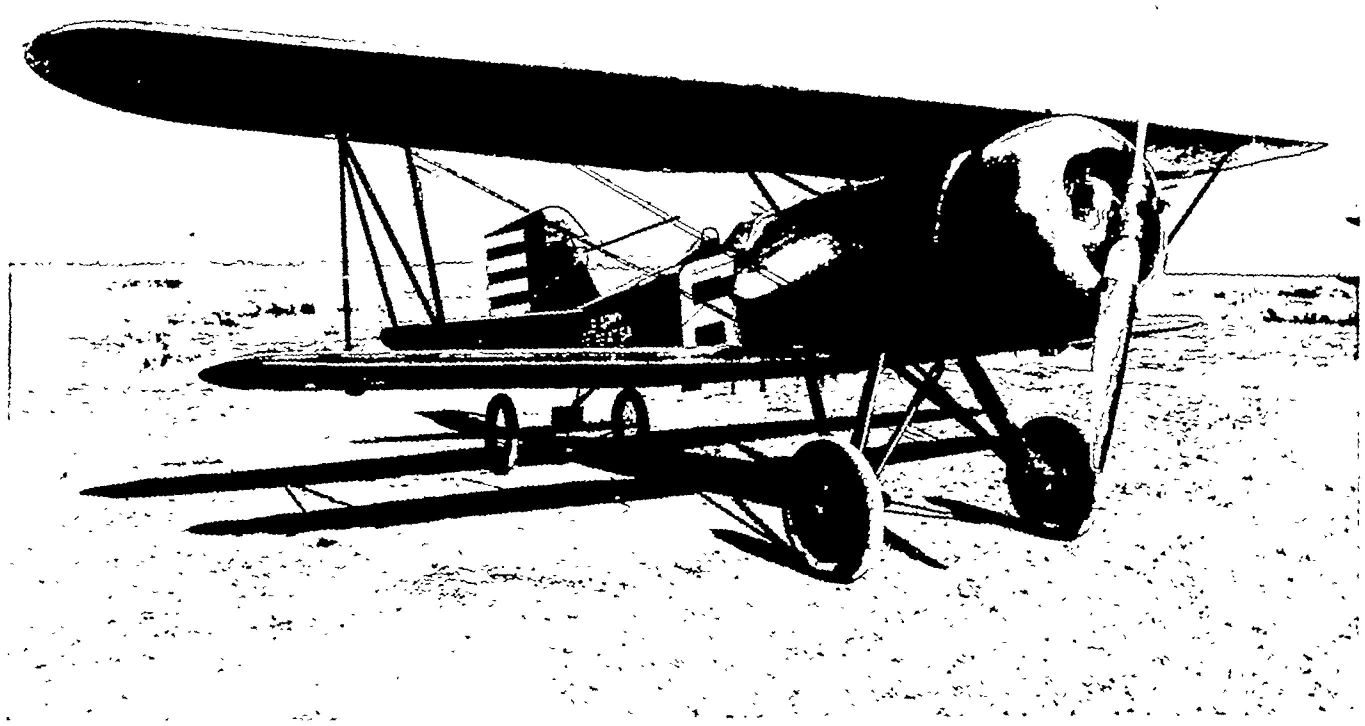
Dr. Joseph S. Ames, member National Advisory Committee for Aeronautics 1915–39; Executive Committee, 1919–37; Chairman, 1927–39.

Dr. Vannevar Bush, member National Advisory Committee for Aeronautics 1938–48; Vice Chairman, 1938–39; Chairman, Executive Committee, 1938–41; Chairman, 1939–41.

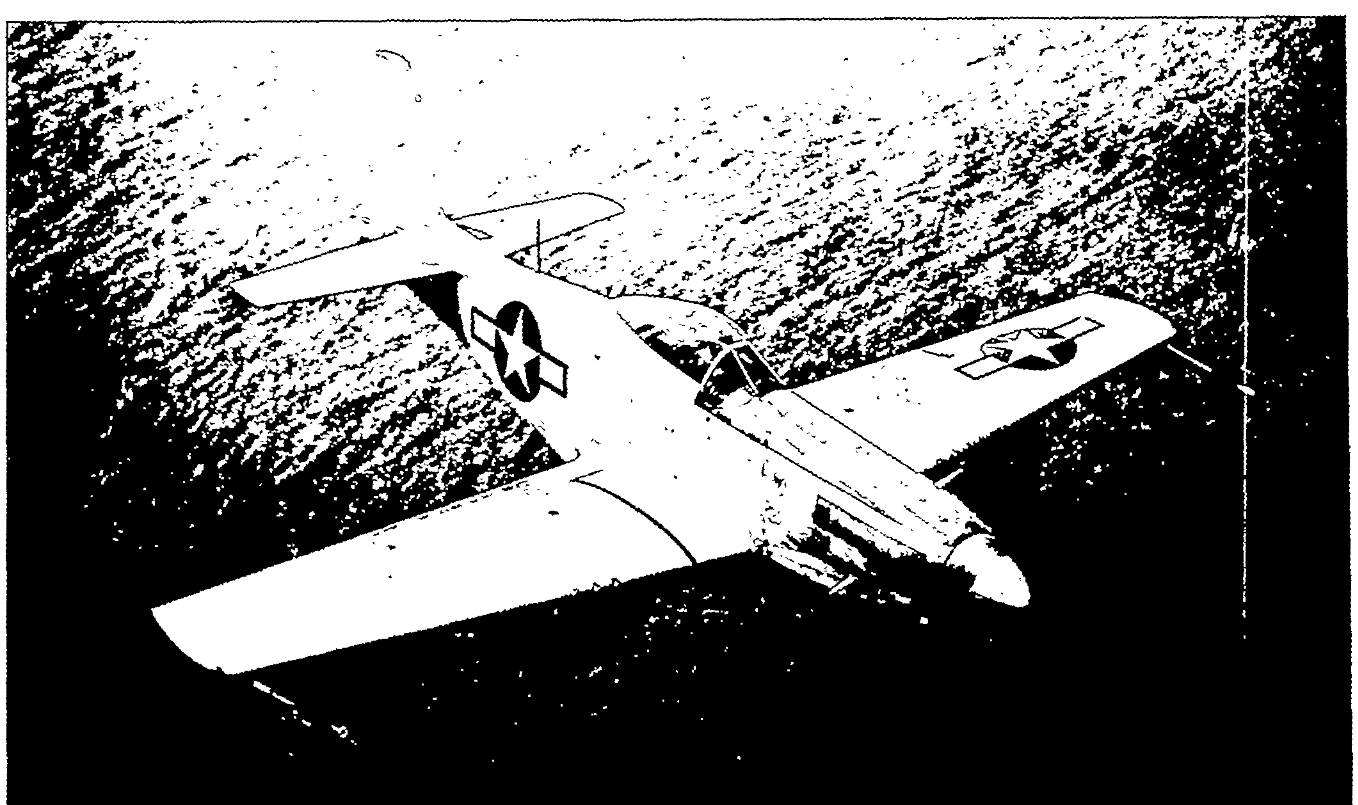
Jerome C. Hunsaker, member National Advisory Committee for Aeronautics 1922–23, 1938–58; Chairman, 1941–56; Chairman, Executive Committee, 1941–56.

James H. Doolittle, member National Advisory Committee for Aeronautics 1948–58; Chairman, 1956–58; Chairman, Executive Committee, 1956–58.

Dr. George W. Lewis, Director of Aeronautical Research, National Advisory Committee for Aeronautics, 1919–47.

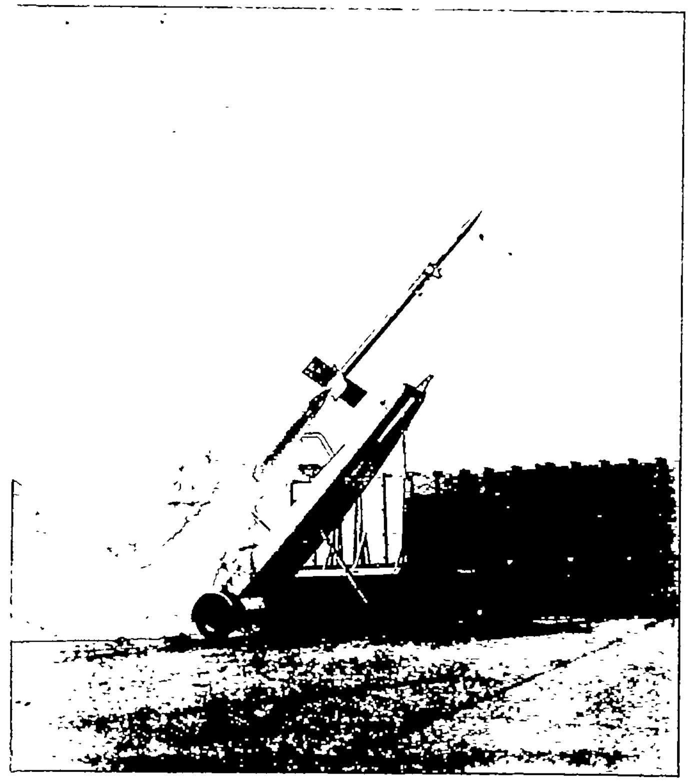


Application of NACA cowling on AT-5A Army pursuit training plane increased its speed from 118 to 137 m.p.h. This was equivalent to providing 83 additional horsepower.



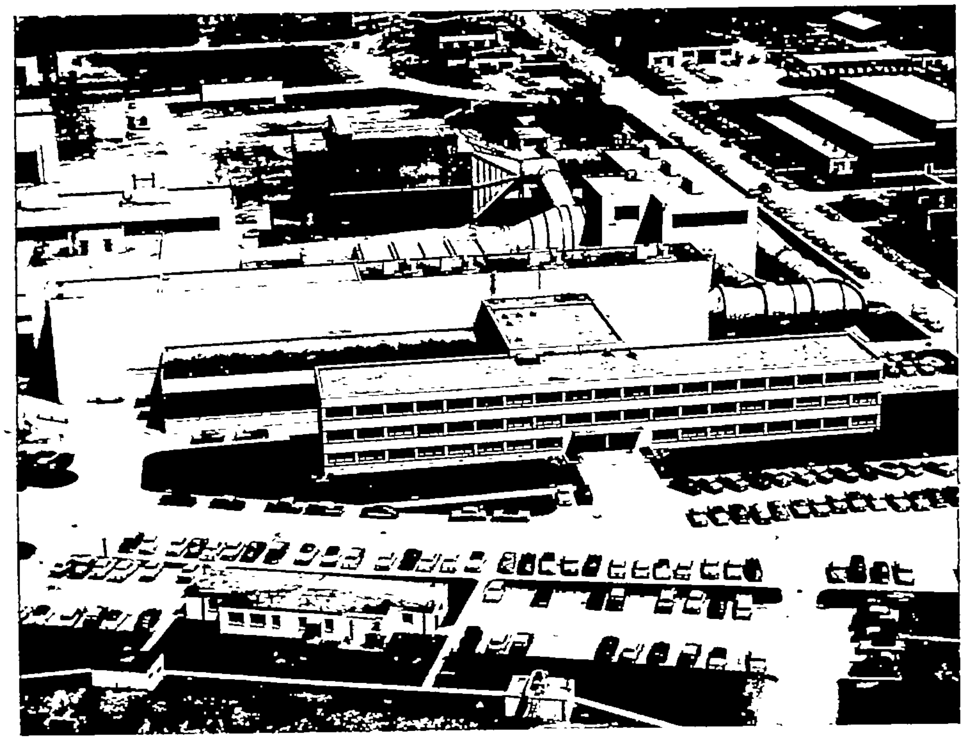
The NACA Langley Laboratory's low-drag wing was first used on the P-51 Mustang fighter, making it the fastest propeller-driven airplane of World War II.

An engineer in NACA's towing tank at Langley Aeronautical Laboratory prepares a dynamic model equipped with hydro-skis for a test run.



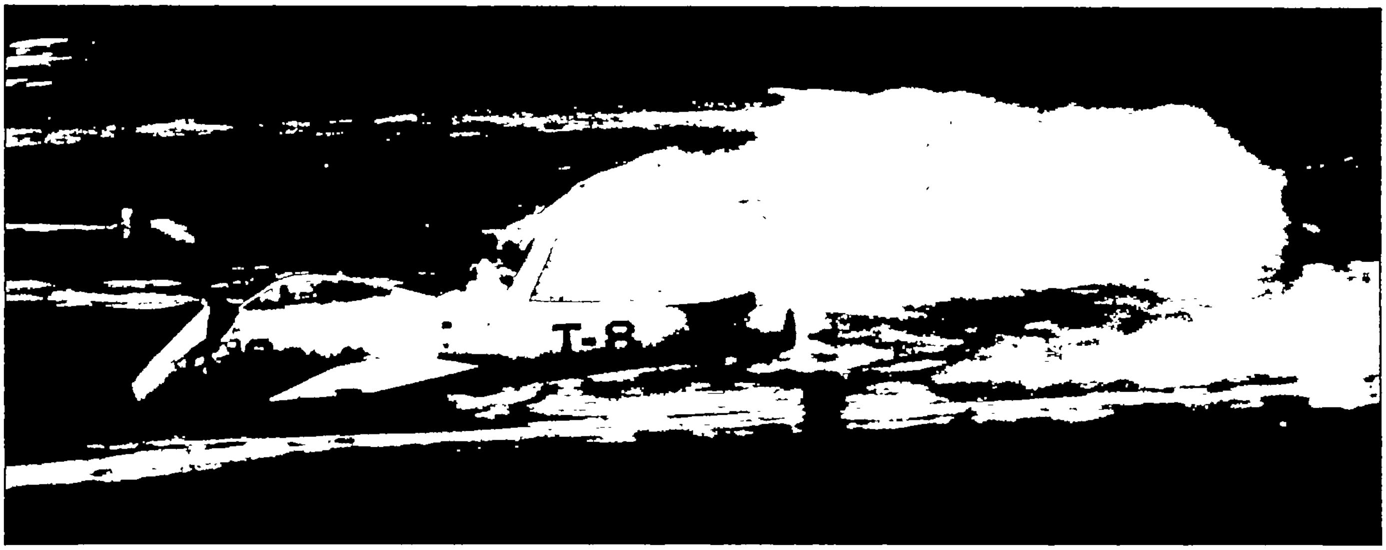
This rocket-powered model, one of a series tested by the NACA to investigate the flutter characteristics of low aspect ratio wings, shoots skyward toward the Atlantic Ocean from its launching ramp at the NACA Pilotless Aircraft Research Station, Wallops Island, Va.

The 14-foot test section of the Ames Unitary Plan wind tunnel. It is capable of operating smoothly from subsonic speeds through the speed of sound to low supersonic values, a region where conventional wind tunnels are not usable, owing to choking. The perforated or slotted walls of the tunnel permit flow disturbances to pass through the open parts while retaining sufficient solid area to guide the air uniformly past the model. Two other test sections operate at speeds up to Mach No. 3.5.

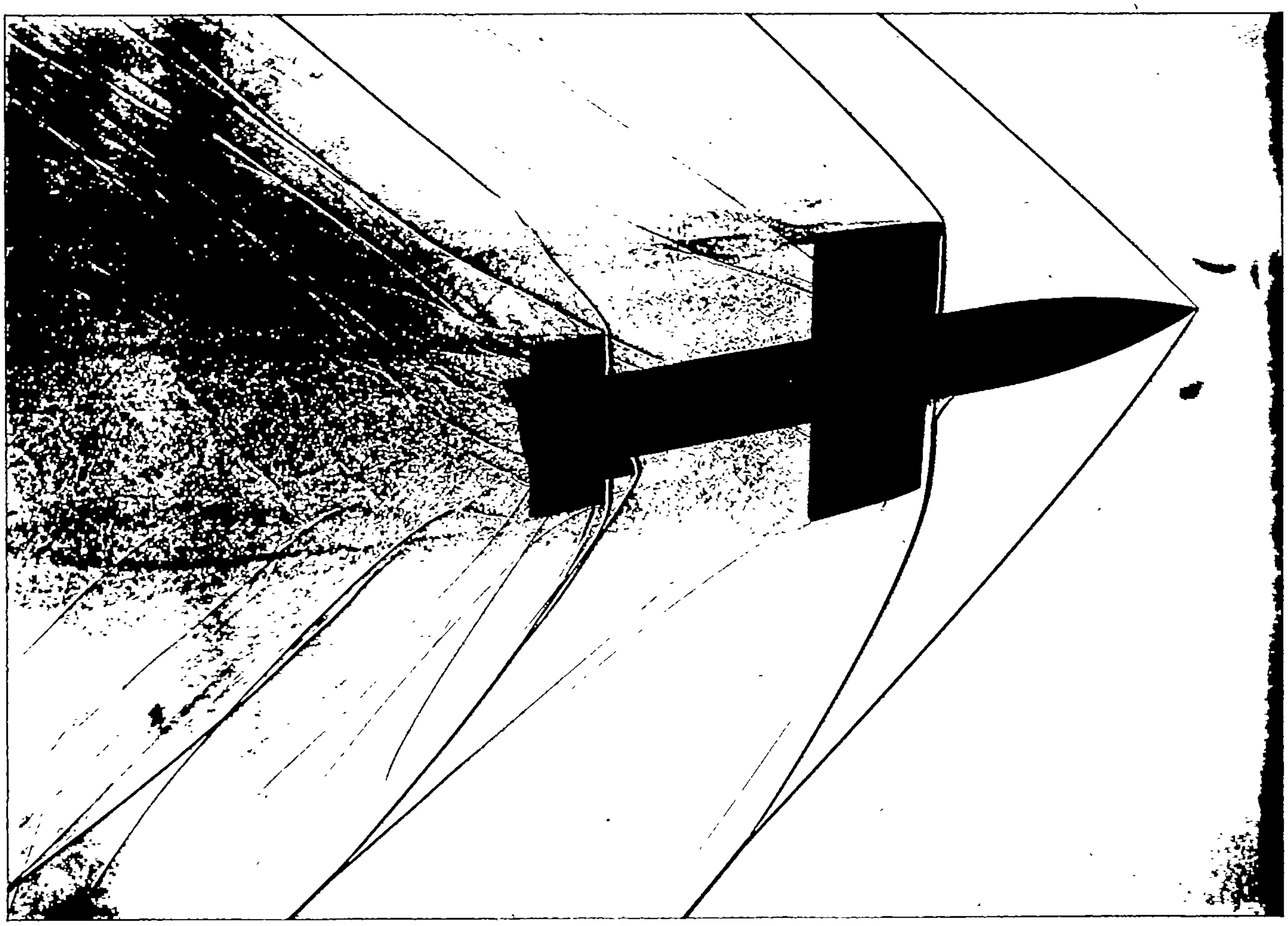


The NACA Lewis Laboratory's new 10-by-10-foot supersonic wind tunnel is used for research on aircraft power plants. This tunnel is designed for speeds of Mach Nos. 2 to 3.5.

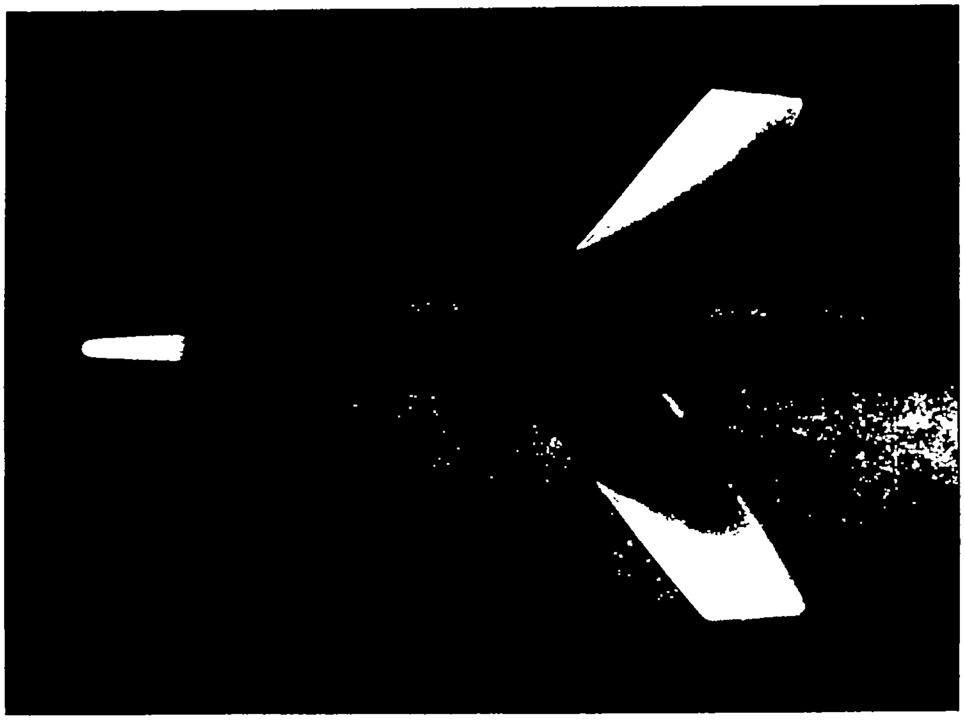
Six dummies, seated in various positions and in several types of seats, rode a service-weary Lodestar transport plane through a severe crash, one of a series staged by a research group of the NACA Lewis Flight Propulsion Laboratory. Objective of the crash program is to gather data on passenger and pilot survival problems in aircraft accidents.



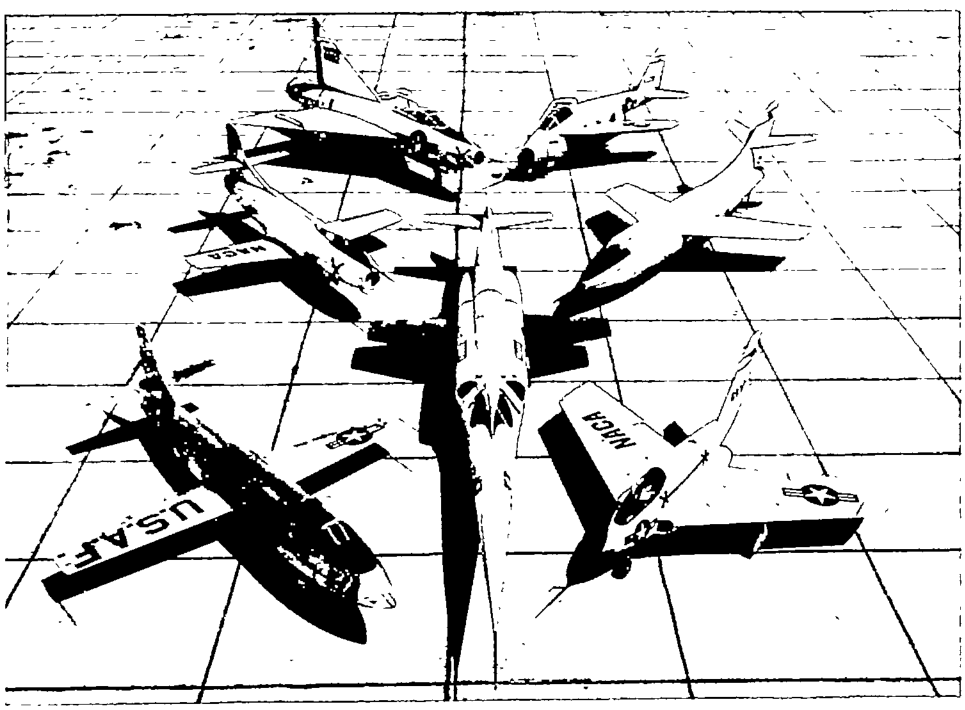
Damage was heavy but fire was prevented in this experimental crash because of a fire-inerting system devised by the NACA Lewis Flight Propulsion Laboratory. A series of crashes was staged with worn-out turbojet- and piston-powered aircraft to study problems of fire and human survival in crash accidents. The white cloud in the picture is jet fuel issuing from the ripped tank in the right wing.



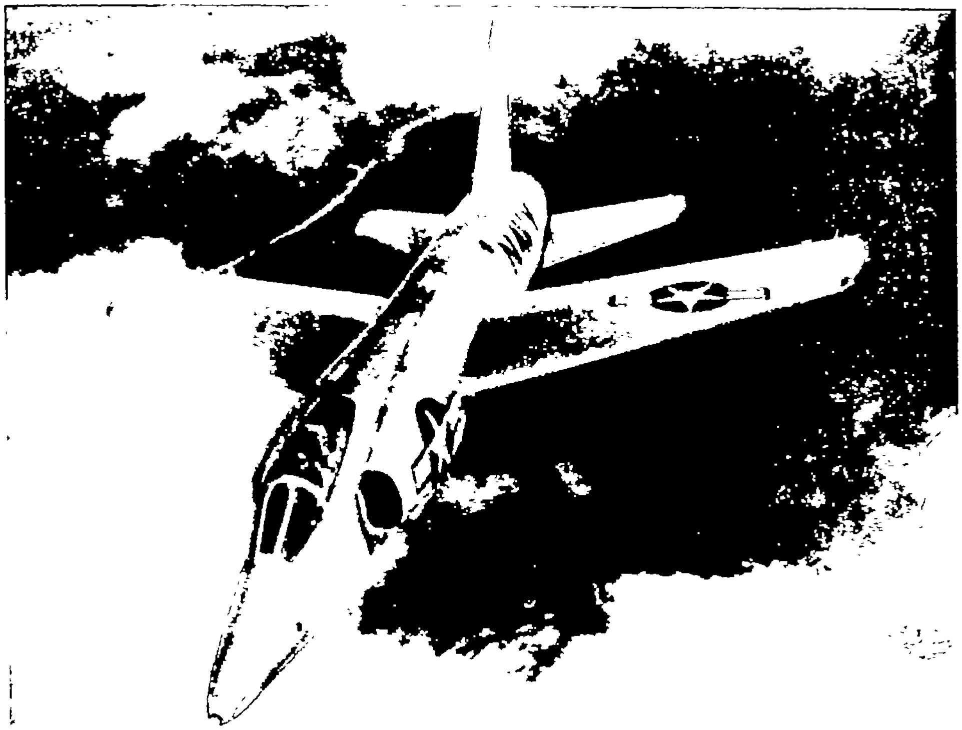
Caught in flight by shadowgraph technique, this free-flight research model shows the complicated pattern of shock waves and vortexes associated with high-speed flight. Vortexes are left in the wake of the model. The unsymmetrical shock-wave pattern shows that the model is turning. The model is 7 inches long and has just been fired from a 3-inch smooth-bore Naval gun into still air. Mach number at the instant of this photograph is 1.6.



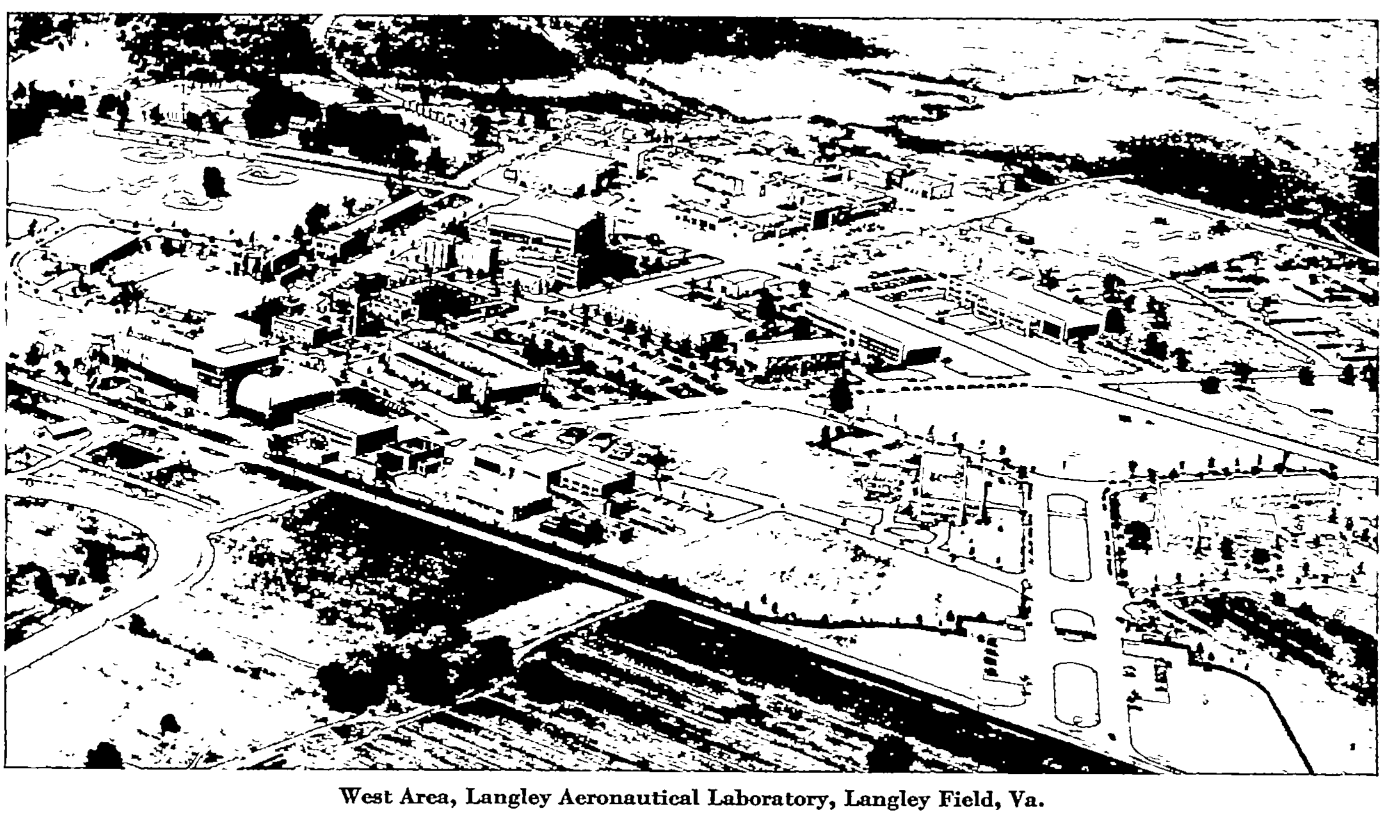
Infrared photograph of a laboratory experiment simulating aerodynamic heating. At 2,000 miles per hour, sustained flight could produce temperatures up to 1,200° F. Much additional research is required to permit successful operation under such conditions.



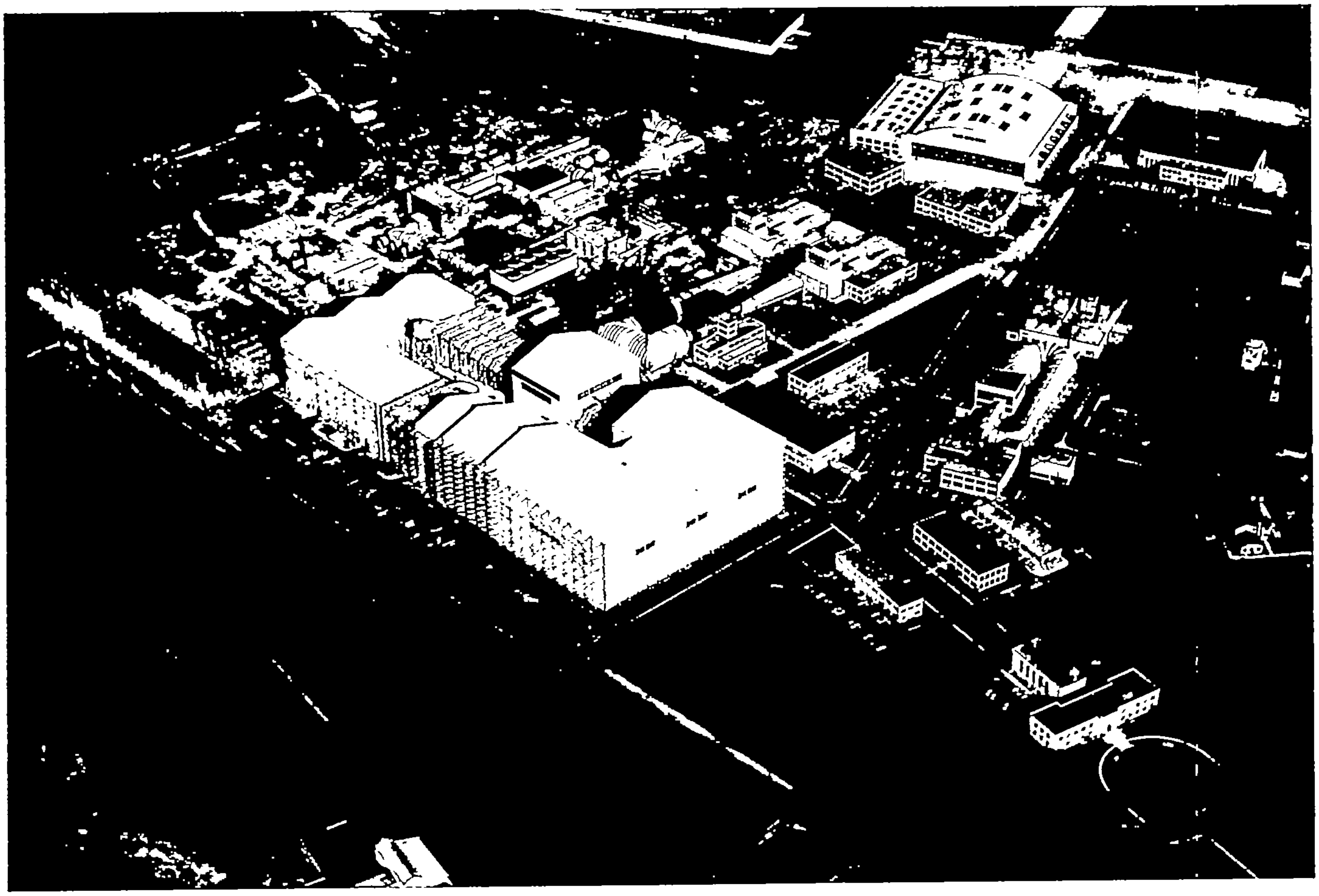
Flying regularly at transonic and supersonic speeds, these research airplanes are exploring new fields for data needed to design the military and civil airplanes of the future. In the center is the Douglas X-3; at lower left, the Bell X-1A flown late in 1953 at a record 1,650 m.p.h. or 2.5 times the speed of sound. Continuing clockwise from the X-1A are the Douglas D-558-I "Skystreak"; Convair XF-92A; Bell X-5 with variable sweepback wings; Douglas D-558-II "Skyrocket," first piloted airplane to fly at twice the speed of sound; and the Northrop X-4. The National Advisory Committee for Aeronautics, the Air Force, the Navy, and the aircraft manufacturing industry are joined to design, build, and fly these and other advanced airplanes in a high-speed flight research program.



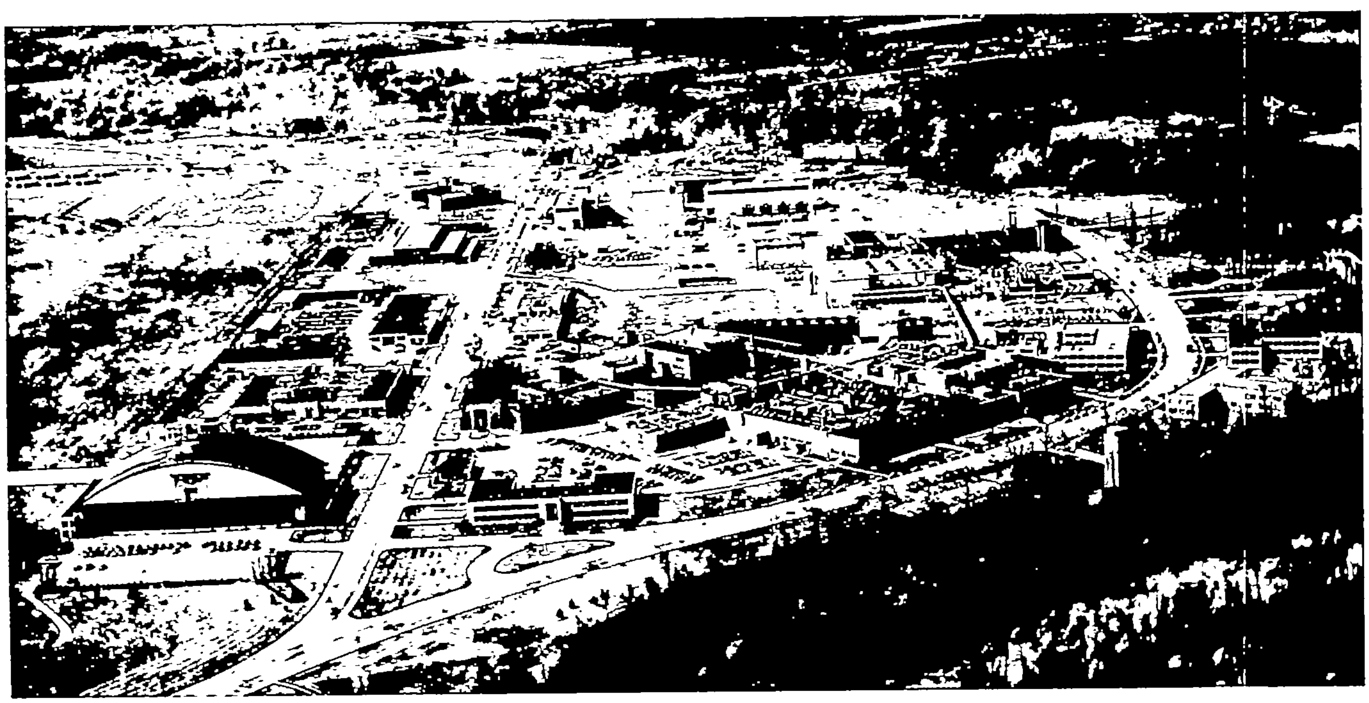
Grumman F11F-1. Use of the NACA-developed "area rule" concept for decreasing drag rise at transonic speeds gave this "Tiger" fighter plane supersonic performance. The "wasp-waisted" Navy carrier plane uses one-third less thrust than other airplanes of equivalent performance.



West Area, Langley Aeronautical Laboratory, Langley Field, Va.



Ames Aeronautical Laboratory, Moffett Field, Calif.



Lewis Flight Propulsion Laboratory, Cleveland, Ohio.

duce operating expenditures, these were successfully resisted, in the main, by such impressive evidence of the money value of the Committee's work as that just cited. On the favorable side was the opportunity for the NACA to construct at depression costs new research equipment with funds already appropriated, and the availability of engineers, from whom many of its future leaders have developed.

The 30- by 60-foot, "full-scale" wind tunnel and the 2,000-foot towing tank (for study of hydrodynamic characteristics of water-based aircraft) were completed in 1931. The designer of the $900,000 "full-scale" wind tunnel (then the world's largest) was Smith J. DeFrance, who became director of the Committee's second research center, at Moffett Field, Calif., when it was established in 1941.

A somewhat later "depression baby" was the 500-mph., 8-foot wind tunnel. For some time after its completion in 1936, it was known, somewhat optimistically, as the "full-speed wind tunnel." Other novel research equipment constructed at Langley in these years included a free-spinning wind tunnel and a refrigerated wind tunnel (for study of icing problems).

In this depression period NACA engineers first disclosed the ability to use air more than once. Soon after the variable-density tunnel was rebuilt following a fire in 1927, it was suggested that some use should be made of the air released each time the tunnel was returned to atmospheric pressure. Why not discharge the pressurized air through an appropriate nozzle and thus obtain a really high-speed airstream? The result was a blowdown device, with a 12-inch test section in which aerodynamic phenomena could be studied at speeds almost that of sound (about 760 mph. at 60° F.).

Thus far, the discussion of research by the NACA has been largely concerned with aerodynamics where the greatest effort was made. Nevertheless there was fruitful work on powerplants, loads, and structures, which will be noted later. In retrospect, one marvels that so much could be accomplished. At the beginning of 1930, for example, the total employment at the Langley Laboratory was only 181.

By the mid-thirties, the work of the NACA had become internationally known and respected. Somewhat earlier the British journal Aircraft Engineering had commented about the Committee: "They were the first to establish, and indeed to visualize, a variable-density tunnel; they have led again with the construction of the 20-foot propeller research tunnel; and . . . [with] a 'full-scale' tunnel in which complete aeroplanes up to 35-foot span can be tested. The present-day American position in all branches of aeronautical knowledge can, without doubt, be attributed mainly to this far-seeing policy and expenditure on up-to-date laboratory equipment."

Somewhat wryly, A. J. Sutton Pippard of the University of London observed in 1953 "that many of our most capable design staffs prefer to base their technical work upon the results of the American NACA."

An important effort of the NACA was to make its research findings fully available for use. First, there were Reports, comprehensive presentations expected to have lasting value. Then there were Technical Notes, preliminary or narrower in scope. Technical Memorandums were reprints, or translations, from the aeronautical literature of other nations. Aircraft Circulars reported information about foreign aircraft and engines. In later years Research Memorandums were added; these were limited in distribution for reasons of military security or because they contained proprietary information.

Recognizing the importance of knowing what was available in the aeronautical literature of the world, Dr. Ames had been instrumental in the formation of an Office of Aeronautical Intelligence as an integral part of the Committee's program, and for years he served both as its director and as chairman of the NACA's subcommittee on publications and intelligence. Beginning soon after World War I and continuing (except for a break in World War II) until 1950, the Committee maintained a technical assistant in Europe. From 1921 the post was held by John Jay Ide, who faithfully and intelligently served the NACA both as European reporter and in a liaison capacity with foreign aeronautical research organizations. It was decided in 1950 to close the NACA's European office because the art and science of aeronautics had become too complex for reportage by a one-man bureau. International exchange of information is now handled by other means.

Beginning in 1926, the Committee sponsored an annual conference at the Langley Laboratory with representatives of the military services and the industry. In addition to the opportunity to see what the NACA was doing, guests had an occasion to criticize and to suggest new research on problems they felt were especially pressing. In the first years of the conference, "everyone" from the industry and the military services attended; even so, the guest list numbered little more than 200, and the journey to and from Langley, via Potomac River steamer, resulted in many unofficial but profitable sessions. After World War II, it became necessary to provide two types of meetings: (1) Technical conferences concerned with a specific subject, usually classified for security reasons, e.g., supersonic aerodynamics. (2) Inspections. Held annually, on a rotating basis at each laboratory, the NACA inspections seek to give the industry and military services a comprehensive view of technical progress. As many as 1,500 attend these meetings, which are not classified.

Also of importance from the standpoint of communication is a steady traffic of industry and military visitors to NACA research centers. Much is accomplished by discussion of matters of specific concern to those involved. No less important are the visits by NACA technical personnel to specific industry plants.

Beginning in the mid-thirties, the NACA reported annually to the Congress and to the President that certain European nations were making a determined effort to achieve technical and quantitative supremacy in aeronautics. Each year the Committee's comments on this subject were stronger. In 1937, for example, Dr. Ames reported: "The greatly increased interest of the major powers in fostering aeronautical research and their determined efforts to excel in this rapidly expanding engineering science constitute a scientific challenge to America's *present* leadership." He explained:

> Up to 1932 the Committee had constructed at its laboratories at Langley Field . . . special equipment such as the variable-density tunnel, the propeller-research tunnel, the full-scale tunnel, and . . . a seaplane towing basin. They were at the time of construction the only such pieces of equipment in the world. The possession of such equipment was one of the chief factors in enabling the United States to become the recognized leader in the technical development of aircraft. Since 1932 this research equipment has been reproduced by foreign countries and in some cases special research equipment . . . abroad . . . is superior to the equipment existing at Langley Field.
>
> This condition has impressed the Committee with the advisability of providing additional facilities promptly as needed for the study of problems that are necessary to be solved, in order that American aircraft development, both military and commercial, will not fall behind.

EXPANSION OF FACILITIES

In 1938, the Committee reported that its laboratory employees at Langley Field were "working under high pressure." It warned that "the recent great expansion of research facilities by other nations will bring to an end the period of American leadership in the technical development of aircraft unless the United States also constructs additional research facilities." Dr. Ames, in October 1938, appointed a Special Committee on Future Research Facilities to make recommendations.

But even before the Special Committee met, the NACA was making a strong recommendation for special facilities for research on aircraft structures. "With the advance in size and speed of aircraft . . . the problems involved require the conduct of laboratory research on structures on an increasing scale," the Committee wrote Congress. "This is the greatest single need for additional research equipment and . . . in the interests of safety and of further progress in aeronautics, it should be provided at the earliest possible date."

On December 30, 1938, the Special Committee recommended immediate establishment of a second NACA research center, in California, to relieve what the late Maj. Gen. Oscar Westover (then Chief of the Army Air Corps and a member of the NACA) called "the congested bottleneck of Langley Field." Although the recommendations had been presented as emergency in character, it was not until midsummer—August 9, 1939—just before the start of World War II, that the second laboratory was authorized by Congress. Hardly a month later, September 14, ground was broken at Moffett Field, some 40 miles south of San Francisco, for what became the Ames Aeronautical Laboratory.

Earlier that year an expansion of Langley facilities was authorized by Congress. S. Paul Johnston (now managing head of the Institute of the Aeronautical Sciences) was named Coordinator of Research to assist Dr. Lewis. Further intensification of research effort obviously was needed in the face of war in Europe, and a second Special Committee, headed by Charles A. Lindbergh, was appointed. This group recommended, October 19, 1939, that a powerplant research center be established at once.

"There is a serious lack of engine research facilities in the United States," Lindbergh's committee stated. "The reason for foreign leadership in certain important types of military aircraft is due in part to the superiority of foreign liquid-cooled engines. At the present time, American facilities for research on aircraft powerplants are inadequate and cannot be compared with the facilities for research in other fields of aviation." It was June 26, 1940—after Belgium and Holland had been overrun—that congressional authorization for the new flight-propulsion laboratory was forthcoming.

A site was made available by the city of Cleveland adjacent to its municipal airport. Immediate steps were taken by Dr. Lewis to plan and construct a complex of laboratories equipped with facilities for the investigation of airplane engines, their parts and materials, fuels and lubricants, ignition and combustion, heat transfer and cooling, intake and exhaust aerodynamics, as well as for the fundamental physics, chemistry, and metallurgy of power generation. In addition, facilities were provided for flight testing in laboratory-instrumented airplanes—practical flying laboratories for propulsion research.

There is no doubt that this flight-propulsion center was a large step in advance of any comparable facility in the world. It has cost up to date about $110 million and now employs about 2,800 people.

After the death of Dr. Lewis in 1948, the Committee decided on the name "Lewis Flight Propulsion Laboratory," as a memorial to that great engineer's crowning achievement.

Here it may be proper to explain why the research effort on powerplants and on structures had been so much less than that devoted to aerodynamics. In the first place, it must be remembered that between World Wars I and II, the United States was an intensely peace-minded nation. In addition, the thousands of miles of ocean to our east and west gave a feeling of safety from attack, a complacent sense of detachment. The Congress was unwilling to expend really large sums for national defense or on research to improve it.

Until the eve of Pearl Harbor, the annual expenditure by the United States to support aeronautical research was indeed modest. Even as late as the summer of 1939, the NACA's total complement was 523, including only 278 technical people.

The major effort by the NACA over the years had been deliberately concentrated on aerodynamic problems. Here, for a given expenditure, the possible gains to be achieved were very large, particularly in view of the relatively few engineers who could be assigned to the work.

Powerplant research and structural research are expensive, and require extensive facilities for full-scale investigations. Small models are of limited utility in powerplant research. Furthermore, powerplants and structures are the immediate concern of strong and highly competitive industrial firms. The Committee evidently felt that under its fiscal restrictions, it would do better to concentrate on basic aerodynamic problems and might, hopefully, leave research and development of powerplants and structures to the industry and the military services.

However, the Lindbergh committee in 1939 said that this past policy was wrong, and the NACA agreed. It appeared that leaving fundamental research to the industry meant, in effect, that such research would be indefinitely postponed.

A competitive engine firm must concentrate on what its customers want. The firm improves its engine with small changes based on experience. It seeks the minimum risk of interruption of production. The military services, its principal customers, conduct competitive trials based on standard performance specifications. After quantity orders are placed, no major changes are possible. The services, of course, welcome small changes based on experience, if the risk of trouble be slight. As a result, engine development tends to adhere to a definite pattern and progresses slowly.

An engine manufacturer must make a relatively heavy investment in plant and tooling for production of a particular engine. The manufacturer is naturally inclined to concentrate on improvements in this engine to prolong its commercial life. These improvements are essentially proprietary in character.

Similar remarks apply to the airplane industry. Every effort is made to improve a particular airplane to prolong its vogue in production. This development effort is restricted to conservative changes in a basic design acceptable to the customer.

In this country, the Navy standardized on air-cooled radial engines that met Navy requirements, while the Army insisted on 12-cylinder, liquid-cooled engines to power the fighters in their program.

However, there were important fundamental applications of science to engine design that needed investigation in 1940.

From the beginning, one of the principal technical committees of the NACA was concerned with powerplants. During World War I, a few research projects in the powerplant field were carried on under its auspices, notably in the altitude facility at the Bureau of Standards, where engines could be operated under conditions simulating those experienced by high-flying aircraft. A program of systematic tests was conducted there for the NACA, including supercharging with a Roots-type blower.

At Langley the small but expert powerplant staff made some important contributions, in addition to their cooperation with the wind-tunnel people in developing the remarkable NACA cowling for air-cooled engines. One recalls improved finning for air-cooled engine cylinders, methods to decrease the octane requirements of high-compression engines, and work on such fundamental matters as the behavior of fuels—how they ignite, how they burn, and how this burning corrodes critical parts of the engine. A principal tool in the study of these latter questions was high-speed photography, and cameras capable of taking pictures at the rate of 400,000 per second were developed by the NACA.

In the field of jet propulsion the NACA exhibited an early awareness of its possible advent but did little about it. In 1923, in Report No. 159, "Jet Propulsion for Airplanes," Edgar Buckingham of the Bureau of Standards, reported that: "The relative fuel consumption and weight of machinery for the jet decrease as the flying speed increases; but at 250 mph. the jet would still take about four times as much fuel per thrust horsepower-hour as the air screw, and the powerplant would be heavier and much more complicated. Propulsion by the reaction of a simple jet cannot compete, in any respect, with air screw propulsion at such flying speeds as are now in prospect." This conclusion was entirely rational on the basis of the technology at that time.

In the early thirties, the NACA was asked by a representative of the airframe industry to resurvey jet-propulsion prospects and, although airplane speeds by then had passed the 250-mph. mark which Buckingham considered a goal, the story was much the same. The inefficiency of the jet engine at the speeds contemplated ruled it out of consideration.

Near the end of the 1930's, some preliminary experimental work on jet propulsion was undertaken at the Langley Laboratory. These experiments indicated that jet engines would be so fuel thirsty as to limit their useful application to very high-speed, very

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short-range aircraft. American thinking, perhaps because of geography, was focused on long-range performance where fuel economy was paramount. This idea served to discourage any real jet-development effort in the United States until intelligence of British and German experiments reached us.

In March 1941, Dr. Durand was recalled from retirement to head a special NACA Committee on Jet Propulsion. The fact that he was in his 82d year was only a matter of calendar counting. The vigor with which he and his committee launched a belated development effort would have done credit to a man less than half his age. Later in 1941, Gen. H. H. Arnold secured from the British one of the earliest of the Whittle jet engines to aid the development program initiated by Dr. Durand. In this program, the Durand committee was handicapped by the fact that the country had just been plunged into a war for which it was ill prepared and the principal airplane-engine firms were overloaded. The decision came "from the summit" that we would fight with the weapons in hand. First priority was given their production in immense quantity. Consequently, the Durand committee had to arrange with nonaeronautical firms to undertake the development of turbojet engines for possible later use to power fighter airplanes.

Over some 20 years, aerodynamic and powerplant improvement, much of it based on application of research results, permitted the top speed of military airplanes and the cruising speed of commercial airplanes to be doubled; the air loads imposed on the faster airplanes were severely increased, especially in rough air and when maneuvering.

The loads research group at the Langley Laboratory consisted of but 20 men in 1939, but their contribution was considerable, notably the V–G recorder (V for velocity, G for gravity) by R. V. Rhode and H. J. E. Reid. It was devised to measure continuously the loads experienced by an airplane flying in rough air. This was but one of many novel instruments which NACA engineers have devised for precise measurements in flight.

The research problem directly related to loads deals with structures to carry the loads. Here again the manpower available at Langley prior to World War II was small; as late as October 1940, only 10 men were working on airplane structures. Their work was concerned, principally, with fundamental knowledge about structures from which a trustworthy theory could be developed for design application. Delicate experiments and mathematical analyses dealing with the behavior of thin-walled cylinders, stiffened panels, and other structural units produced useful conclusions that were used on our World War II aircraft.

On October 7, 1939, Dr. Ames resigned from the Committee because of failing health. His responsibilities as chairman of the Committee were given to Dr. Vannevar Bush, who had been serving both as vice chairman and as chairman of the executive committee.

Note has been made already of the manner in which Dr. Ames had provided leadership of the highest quality to the Committee for nearly a quarter-century. The letter President Roosevelt wrote upon the occasion of his retirement contained this statement:

> Our Republic would not be worthy of the devoted service you have rendered for over 24 years without compensation if it could not on this occasion pause to pay tribute where it is so justly due. . . . That the people generally have not known of your brilliant and patriotic service is because it has been overshadowed by your passion for accomplishment without publicity. But the fact remains, and I am happy to give you credit, that the remarkable progress for many years in the improvement of the performance, efficiency, and safety of American aircraft, both military and commercial, has been due largely to your own inspiring leadership in the development of new research facilities and in the orderly prosecution of comprehensive research programs.

The Committee resolution, tendered to Dr. Ames in Baltimore by a special delegation, said:

> When aeronautical science was struggling to discover its fundamentals, his was the vision that saw the need for novel research facilities and for organized and sustained prosecution of scientific laboratory research. His was the professional courage that led the Committee along scientific paths to important discoveries and contributions to progress that have placed the United States in the forefront of progressive nations in the development of aeronautics. His was the executive ability and far-sighted policy of public service that, without seeking credit for himself or for the Committee, developed a research organization that holds the confidence of the governmental and industrial agencies concerned, and commands the respect of the aeronautical world. Withal, Dr. Ames was an inspiring leader of men and a man beloved by all his colleagues because of his rare qualities.

In July 1941, the President appointed Dr. Bush director of the newly established Office of Scientific Research and Development, and he resigned as chairman of the NACA. The writer was elected chairman, an honor he has been privileged since to hold.

WORLD WAR II AND AFTER

The war years for the NACA were plagued by the necessity for rapid expansion of the civil service staff from hardly 500 in 1939 to more than 6,800. Trained engineering personnel were unavailable. Consequently, it was mandatory that professionals be spread ever thinner, while loom fixers, toymakers, mechanics, blacksmiths, and women schoolteachers were recruited for jobs they could do or for which quick instruction could be given.

Especially in the matter of skilled management of research programs, the NACA might have been expected to be sorely weak. And yet, somehow, with each expansion of effort, new leaders were found from within the permanent NACA staff. No sooner did Henry

J. E. Reid, director of the Langley Laboratory, see some of his best men on their way to build the new laboratory at Moffet Field—named in 1944 in honor of Dr. Ames—than the process of designating the leaders of the new engine laboratory—named in honor of Dr. Lewis in 1948—was begun. Smith J. DeFrance was named director of the Ames Aeronautical Laboratory, and later Edward R. Sharp became director of the Lewis Flight Propulsion Laboratory. Both of these men were senior members of the permanent staff at Langley.

NACA's war effort was of necessity devoted very largely to applied research, the business of finding "quick fixes" to make existing aircraft better performers, and production engines more powerful. Fortunately, a considerable backlog of design data was available for application to such subjects as low-drag wings, high-speed propellers, stability and control, and improved systems for cowling and cooling engines. Between December 1941 and December 1944, the Committee's research centers worked on 115 different airplane types. In July 1944, 78 different models were under simultaneous investigation.

Perhaps the best comment on the value of NACA's World War II work is to quote from a statement by the late Frank Knox, made in 1943 when he was Secretary of the Navy:

> New ideas are weapons of immense significance. The United States Navy was the first to develop aircraft capable of vertical dive bombing; this was made possible by the prosecution of a program of scientific research by the NACA. The Navy's famous fighters—the Corsair, Wildcat, and Hellcat—are possible only because they were based on fundamentals developed by the NACA. All of them use NACA wing sections, NACA cooling methods, NACA high-lift devices. The great sea victories that have broken Japan's expanding grip in the Pacific would not have been possible without the contributions of the NACA.

The end of World War II marked the end of the development of the airplane as conceived by Wilbur and Orville Wright. The power available in the newly developed turbojet and rocket engines for the first time brought within man's reach flight through and beyond the speed of sound.

In the years following World War II there were changes, too, in the membership of the Committee. In 1948, the death of Orville Wright closed 28 years of his membership on the NACA. Though he was but one among many strong men who had given of time and talent to the work of the Committee, his passing sharpened the realization that in the working years of one man's life—between December 17, 1903, and January 30, 1948—the speed of the airplane had been increased from hardly 30 mph. to almost 1,000 mph.

In 1948 the membership of the Committee was increased to 17. This permitted the inclusion of a representative from the Department of Defense, presently the Assistant Secretary (Research and Development). Since the war the Committee has included one Presidentially appointed member from the airframe, the engine, and the air-transport industries, thus insuring awareness of the needs of those major segments of American airpower.

In 1948 Dr. Lewis died. In 1945, his health broken by the war effort, he had been forced to withdraw from active participation in the work of the Committee. For almost 2 years, John W. Crowley, Jr., served as acting director of aeronautical research. With the Committee since 1921, Crowley had been chief of research at Langley for a number of years. He provided vitally needed leadership during a critical period.

To succeed Dr. Lewis, the Committee in 1947 chose the Associate Director of the National Bureau of Standards, Dr. Hugh L. Dryden. He was no stranger to the NACA. Trained in physics and mathematics by Dr. Ames at Johns Hopkins University, he had gone to the Bureau of Standards in 1917, where he soon earned an international reputation by his aerodynamic researches in turbulence and boundary layer. His new task at the NACA was extremely difficult, yet it was vital to the Nation that a "new look" at the postwar situation be taken, and new objectives defined in terms of supersonic jet-propelled vehicles potentially available for the worldwide exercise of air power and, eventually, for civil air transportation.

At the end of World War II, the most urgently sought goal was attainment of practical flight at supersonic speed. It was realized that success in this effort required new knowledge which could be obtained only with new tools and new techniques. Even before the end of the war efforts were made to acquire needed data. Efforts to develop useful transonic aerodynamic theory had failed and it was necessary to resort to direct experimentation at velocities passing through the speed of sound. The fact that the principal tool of aerodynamic research, the wind tunnel, was subject to "choking" phenomena near the speed of sound forbade its use for the critical experimentation. Entirely new techniques had to be devised. The NACA's attack was broadened to include all approaches which offered promise.

The earliest attempt used especially instrumented aerodynamic bodies dropped from a high altitude, but it was not until late in 1943 that advances in radar and radiotelemetering equipment made it possible to obtain reliable data by this method. Even then, the velocity of a free-falling body seldom went much beyond a Mach number of 1 (M=1 equals the speed of sound).

Other attempts sought to use the acceleration of airflow above a curved surface. Small model wings were mounted near the leading edge of the wing of an airplane. In this way, lift, drag, and other aerodynamic characteristics of the model were measured. The method was employed also to study stability and trim of airplane shapes in the transonic speed range. The same principle of accelerating airflow was tried with small models positioned over a "hump" in the test section of a subsonic wind tunnel, but scale effects complicated the interpretation of test results for use in design.

Use of rocket-propelled models fired from the ground followed the first work with free-falling bodies by about a year. As instrumentation has been improved, this technique has become a valuable tool for transonic research. By the addition of powerful booster rockets, models of this kind are being used to study aerodynamic problems at speeds ranging up to a Mach number of 10 and higher. The fact that very high speeds are reached at low altitude, where the air is dense, makes the aerodynamic data readily usable for plane and missile design. In 1945, the NACA established a Pilotless Aircraft Research Station at Wallops Island off the Virginia coast, to carry on this work. It is attached to the Langley Laboratory.

In 1943, the idea was advanced of using specially designed piloted airplanes to explore the transonic speed range. Propelled by powerful rocket engines and provided with elaborate data-recording equipment, the research airplane could be safely flown at high altitudes where the density of the air, and hence the loads imposed on the structure, would be low.

The spectacular accomplishments of the research airplanes—the supersonic flight of the Bell X–1, October 14, 1947; the twice-the-speed-of-sound flight of the Douglas D–558–II, November 20, 1953, and the even faster flights of the Bell X–1–A which followed soon after—have sometimes obscured the fact that these airplanes were tools for research. These flights are historic; all agreed as to the rightness of the Collier Trophy award to three men for the year 1947: John Stack, Langley Laboratory, for conception of the research airplane program; Lawrence D. Bell, for design and construction of the X–1; and Capt. Charles E. Yeager, USAF, for making the first supersonic flight.

But even more valuable than the dispelling of the myth about the sound barrier was the accumulation of information about the transonic speed region. The shape and the performance of tactical military aircraft which have been designed since reflect the use of data obtained by the research airplane program centered at the NACA's High-Speed Flight Station at Edwards Air Force Base, Calif.

Despite the success of this flight program, there remained the need for a technique whereby transonic experimentation could be carried on under the closely controlled conditions possible only in the laboratory. Actually, the data coming from the research airplanes accented this need, because they pointed up the fundamental problems of fluid mechanics that would have to be studied in great detail for the design of useful supersonic aircraft.

By late 1950, following intensive theoretical work, there was put into operation at the Langley Laboratory a new type of wind tunnel. Incorporating a "slotted throat" at the test section, it was free from choking near the speed of sound and truly could be described as a transonic wind tunnel. Again, the Collier Trophy was awarded to John Stack and his Langley associates for the conception, design, and construction of this most useful research tool.

One must appreciate the very great difference between airplane design in the past and today. In the past, the difference between the best design and the second best, assuming the same power, might be at most only a few miles an hour. Now the difference may be measured in hundreds of miles an hour. The art is being extended so rapidly that no longer is there a comfortable time margin between the acquisition of research data and its application.

Hardly had the first of the NACA's transonic wind tunnels gone into full operation, in 1951, when Richard T. Whitcomb, a young engineer at the Langley Laboratory, began the experimental verification of what has since become known as the "area rule." In essence, Whitcomb worked out a rational way to balance the lengthwise distribution of volume of fuselage and wings to produce an airplane form with minimum drag at high speeds. Seemingly slight modifications to the shape of the airplane fuselage greatly improved performance.

As soon as the new design principle was verified in preliminary form, it was made available in confidence to the designers of military airplanes and the new information was promptly applied.

In one instance, the prototype of a new fighter aircraft was unable on test to attain supersonic speeds. With the deceptively subtle modifications dictated by the "area rule," the airplane enjoyed a performance gain in speed of as much as 25 percent.

At the velocities contemplated for our future missiles and airplanes, temperatures measured in thousands of degrees Fahrenheit will be encountered owing to aerodynamic heating—friction. The consequent structural problems are little short of fantastic and, with presently available materials of construction, the solution is not in sight. More research is needed.

The performance possible from the harnessing of nuclear energy for airplane propulsion would be nonstop flight over virtually unlimited range. Again, one is faced with problems of enormous complexity and difficulty, but national security requires that research and development be carried forward with imagination and vigor.

Millions of passengers are now carried by air. Air transportation also expedites the delivery of great volumes of mail and goods. Airliners regularly span oceans and continents, and smaller utility planes serve remote regions in the Arctic and tropical jungles. There is promise of helicopter service between nearby cities, with no need for large outlying airports.

The safety record of civil aeronautics is remarkably good, but it is never good enough. We still read, from time to time, of disasters from collision, fire, storm, human error, and, rarely, from structural or mechanical failure of the airplane itself. The human pilot is aided by wonderful instruments and by radio, radar, gyros, etc., but we still depend on his judgment and skill. He must be better protected against noise and fatigue—subjects for research.

Air transportation is fast and can be faster. But greater flight speed is illusory if it requires too long a climb to reach the high altitude necessary for economy. Furthermore, higher speed airplanes tend to require longer runways and bigger airports. This could mean a new program of airport building at colossal expense, with the new airports even farther from the passengers' ultimate destination. Getting to and from the airport could consume more time than is saved by faster flight. Research continues on improving landing and takeoff characteristics of airliners.

It may be that airliners of the future will be designed to the limitations of the airports they are to serve, just as transatlantic steamers are designed to enter only a few major seaports, where the channel and piers have adequate depth of water.

Civil aeronautics can make its greatest contribution to trade and commerce under a favorable international climate of free interchange of people, goods, and ideas. Greater economy, efficiency, and safety are prerequisites for its full utilization. Research can show the way to advance toward these goals.

Through the years the NACA has been provided by Congress with the most modern research equipment at a total cost of approximately $300 million, and the present operating staff numbers about 7,600 persons, of whom over 2,000 have professional degrees. These resources, in the present hostile and threatening international climate, are directed for the most part toward research helpful to national security. Research to improve military aircraft is ultimately applied to civil aviation, when proved to be thoroughly practical by experience, but there are differences in emphasis, because safety, comfort, and economy are relatively more important in civil airplanes. The Committee has numerous investigations in progress which are directed toward the immediate problems of civil aviation, as for example the work on noise, icing, fire prevention, atmospheric turbulence, and reduction of landing speed.

A more favorable international climate would permit greater emphasis on civil aviation, but it is likely that for some time to come the national security will require a great effort to penetrate more rapidly into the vast region of the unexplored and unknown. The Committee feels its responsibility for guidance of the overall research effort in aeronautics, and it is hoped that through its work aeronautics may make the maximum possible contribution to human welfare.

The Following Years

1955–58

By James H. Doolittle
Chairman NACA, 1956–58

The latter years of the NACA were among its most productive. It was almost as if the talented scientists and engineers of the organization during the years of World War II when they were so intensively engaged in efforts to improve current airplanes, had been saving up bold, big ideas about how to accomplish dramatic improvements in aircraft performance. Once peace was restored, even though it was soon to prove an ephemeral thing, there was a steady flow from the people at the Langley, Ames, and Lewis Laboratories, of new information about the laws governing flight that the designers of the industry could incorporate quickly into their new aircraft. Much of what I shall describe in this brief summary belongs, really, to the 40-year period covered by Dr. J. C. Hunsaker's preceding account of the NACA. The principal reason he could not include this information was security. There is much more I should like to say about current work, but again, some of the story must await a future occasion.

One of the most important aspects of NACA research during the postwar years was the systematic study of such problems as aircraft and rocket fuels. Any high school or college chemistry student can look at the charts and determine that hydrogen has the highest energy content per pound and therefore should be a principal element in the ideal fuel, the one that will produce the most thrust per pound. The goal is to devise such an ideal fuel and methods of practical use in the face of such obstacles as toxicity, availability, cost, etc. Here, there is no easy quick path to accomplishment; hard work, sustained research over long periods, is the only sure way to success.

At the Lewis Laboratory, beginning with the closing days of the war, a program to develop "super fuels" was begun that, even in mid-1958, is still producing useful information. Progress, long-range progress, has been and continues to be made, despite a succession of inevitable disappointments. One promising lead after another had to be studied and discharged until it became known that the answers were to be found elsewhere. Finally, of course, this systematic effort pointed toward the "best answers."

For example, one way to obtain more powerful, more useful fuels was to burn such materials as aluminum or magnesium. The problems of compounding slurries of these metals had to be solved, but when solutions to these problems were found, the realization followed that this approach was not useful, for reasons that need not be dealt with here. Other solutions to the problem had to be sought. In passing, I should like to emphasize that in the business of learning how to fly faster, higher, and farther, it is sometimes very important to *learn what won't work*. With this essentially negative information in hand, it then becomes possible to work rapidly and surely toward goals that will pay off.

Even today, the subject of "exotic fuels" remains heavily classified. I may state, however, that basic produce the most thrust per pound. The goal is to de-work by scientists and engineers at the Lewis Flight Propulsion Laboratory on fuels incorporating boron compounds has been so successful that large industrial plants have been built to produce these new fuels. They will be used to send our new bombers and interceptors to speeds approaching or exceeding 3 times that of sound (2,000 mph) over very long ranges.

Before turning to other aspects of NACA research, it is appropriate to mention the work being done to find ways and means of providing rocket motors having the greater thrust needed by the ballistic missiles of today and the spacecraft of tomorrow. These efforts include studies of such basic fuel components as hydrogen and fluorine. Slightly farther away on the time scale is the development of engines utilizing nuclear energy. Here, the NACA people have been in closest cooperation with their opposite numbers in the Atomic Energy Commission. Again it is too early to describe in detail the progress that has been made; we must be content to observe that substantial progress is being made. Also some time in the future will come exploitation of "electric propulsion," including such devices as ion jets and plasma jets. We must succeed in learning how to design and build these completely new engines by the day, not too distant, when we shall be ready to launch voyages of discovery to Venus and Mars, and beyond. A good start has been made; there is much more to do.

In the area of aerodynamic loads and structures, the goal remains much the same as in the earliest days of NACA, to learn how to make our airplane structure, and more recently, our missile and spacecraft structures, strong enough to withstand the greater loads imposed by the greater speeds we are attaining, with, of course, the continuing stipulation that our structures contain not 1 ounce of unnecessary weight. The total structures problem is made the more difficult because our airplanes have attained speeds where aerodynamic heating—air friction—imposes new and more difficult requirements. We have to think in terms of materials that will maintain their high-strength characteristics at temperatures beyond the 1,000° F mark. We have to take into account problems of thermal stress that, by themselves, are complicated and hard to solve. And, all the time, we have to remember that weight must be kept to the absolute minimum. All this has made necessary the calculation, to the closest numbers possible, of the structural requirements that will just satisfy our needs.

Difficult as is this problem with respect to airplanes and guided missiles, it becomes even more challenging in the cases of ballistic missiles and space vehicles. The ballistic missile arches high into space on its way to the target. Most of its flight is at speeds measured in thousands of miles per hour. During reentry into the atmosphere it is subjected to heating problems many times more severe than those affecting the high-speed airplanes mentioned earlier. Spacecraft, as they return to earth, will experience not only very serious heating problems but difficult deceleration problems. The decelerational loads imposed on structure, instrumentation, and passengers must all be within tolerable limits. Spacecraft requirements also are so weight sensitive as to be enormously more difficult to meet than is the case with the airplane.

Research in this area has made necessary the design and construction of novel facilities in which the complex problem can be broken down into solvable parts, and studied under the precisely controlled conditions of the laboratory. The NACA has been a leader in this area, and its new facilities are already producing research information that is immediately useful.

One result of such research that has been especially valuable was development of the "waffle grid" concept of construction. Systematic studies demonstrated the value, both structurally and as a weight saver, of plates that were strengthened and lightened by cutting away metal, either mechanically or by chemical etching, on the inner surface. Today the design of virtually all ballistic missiles and spacecraft makes extensive use of the "waffle grid" concept, and its use is hardly less extensive in the newest airplane designs.

Not unrelated to the structural heating problem is the successful development of H. Julian Allen's "blunt nose" concept. Although Allen's concept, worked out at the Ames Aeronautical Laboratory, was essentially completed in 1952, it was not until 1957 that public disclosure became possible.

In essence, Allen's concept called for a complete reversal of the existing practice of designing ballistic missile warheads with a finely pointed, low drag shape. Instead, he proposed a blunt-nose shape which would create a very high-pressure drag during the reentry phase of flight, where aerodynamic heating was so critical. In this way, he reasoned, most of the heat would be dissipated in the region of the shock wave. To reduce this dramatic story to its barest essentials, Allen's work was verified in special, new laboratory apparatus, and today, every U.S. ballistic missile warhead is designed in accordance with his once radical precepts.

The X–15 is the most recent of research airplanes. It is a direct result of research studies by the NACA that were begun in 1952. The Air Force and Navy agreed on the need for such a project and on a plan of joint financing by contracting with North American Aviation for complete design and construction. The X–15 is intended to be used to provide for full-scale scientific investigations in flight of such space flight problems as weightlessness, reentry heating, and control at altitudes approaching 100 miles, where aerodynamic forces are no longer effective, and at speeds exceeding 3,600 miles per hour. The X–15, however, is definitely not a spacecraft. Rather, it is a vehicle that will permit studying problems that must be solved to enable space flight. It is a successor to the earlier research airplanes of the "X series," and, like them, is a joint venture, with the military services, the aircraft industry, and the NACA working smoothly as a team.

Here it may be pertinent to note that for the past dozen years the research programs of the NACA have been undergoing a gradual change in emphasis, away from airplane problems toward missile and space problems. To be sure, many of the problem areas were of interest and concern to designers of airplanes as well as of missiles and spacecraft. Nonetheless, the reorientation process has been positive and, in fact, accelerating. By the end of the fiscal year, June 30, 1958, approximately 50 percent of the NACA research effort was being devoted to problems affecting missiles and space vehicles.

But, as has been said so often and so forcefully, the military airplane is not yet facing extinction, and NACA research in recent years has contributed importantly to the continued worth of manned aircraft. The Convair B–58, America's first supersonic bomber, makes use of Whitcomb's area-rule principle, described in Dr. Hunsaker's account, and of the conical camber concept developed at the Ames Laboratory. The North American B–70, often described in the newspapers as the "Mach 3 chemical bomber," has yet to fly. When it does, it will incorporate much in the way of NACA research information that still has high security classification and cannot be mentioned. In the lower speed ranges, Whitcomb's work is being applied to commercial turbojet transport design, in the case of the Convair 600.

Despite the seemingly insatiable demand for more speed, in both military and commercial categories, the NACA has been aware of the need for continued research in the areas of the "low and the slow." Aircraft with the capability to take off and land, either vertically or with short runs, continue to be of interest, and progress has been made in solving problems peculiar to this type. Similarly, the Nation's flight research agency has done important work on such special matters as aircraft noise and operating problems.

Perhaps the most accurate assessment of the effectiveness of the NACA organization—its 8,000 technical and supporting personnel, its $300 million of laboratories, and its comprehensive research programs—came on July 29, 1958, when President Eisenhower signed the National Aeronautics and Space Act of 1958 that created the National Aeronautics and Space Administration. That act provided that the new agency be built upon the NACA as its nucleus. In this way, the lawmakers made sure that the country gained a running start on its bold, exciting ventures in space exploration for "peaceful purposes for the benefit of all mankind."

AERODYNAMIC RESEARCH

With the rapid advent of satellite, ballistic missile, and other hypervelocity vehicle operation, the NACA has intensified its aerodynamic research of both a basic and applied nature on problems of hypervelocity flight. All such vehicles have severe aerodynamic problems during operation within the atmosphere. Studies bearing on advanced flight concepts, aerodynamic heating and stability of reentry and hypersonic boost-glide vehicles, automatic guidance and stability and control of antiballistic missiles have all been pursued vigorously. Likewise emphasis has been placed on equally important basic gas dynamics research dealing with such subjects as high-temperature gas flows, dissociation and ionization phenomena, air properties at high speeds and temperatures, and magnetogasdynamics principles. Experimental investigations have encompassed temperatures up to 15,000° F. in arc jets, 25,000° F. in shock tubes, and speeds of more than 16,000 miles per hour. Such studies are providing new knowledge imperative for the success of launching man into space, with his safe return to earth assured.

The need for improvements in the efficiency as well as the speed, stability, control, and flying qualities of aircraft and conventional missiles has continued to merit a major part of the NACA research effort. The information obtained is being applied rapidly in new aircraft and missile designs. Unfortunately, aircraft for more efficient operation at the higher speeds have aggravated landing and takeoff problems. An important part of the NACA's research effort is being directed toward improving the low-speed characteristics and establishing low-speed piloting techniques of both high-speed and VTOL/STOL-type aircraft.

As may be seen from the following pages, aerodynamic research encompasses a speed range from takeoff to satellite velocity.

FLUID MECHANICS

Many problems in fluid mechanics, still very incompletely understood, are generated by ballistic missiles, hypersonic gliders, and satellites or space vehicles. Aerodynamic heating is a major factor in determining weight and propulsion requirements of these vehicles, and reduction in heating rates and heating loads pays large dividends. Thus, it is of the utmost urgency that methods of minimizing heat transfer and optimizing vehicle configurations be found. Progress has been made both along the lines of practical solutions to these problems and increased fundamental understanding of the underlying basic fluid flow and gas dynamic phenomena. In spite of the fact that at the high gas temperatures encountered in the flow about hypersonic vehicles, real-gas effects such as dissociation and ionization play an important role, much knowledge has been gained by considering air as a perfect gas. However, an important fact is that the ionized gas in the flow about a hypersonic vehicle permits electrical and magnetic fields to exert forces on the charged particles themselves, thus introducing the whole field of magnetogasdynamics. Activity has increased in this field of research having potential application to the reduction of heat transfer to the surfaces of hypersonic and space vehicles and in the generation of magnetohydrodynamic forces for vehicle lift, control, and propulsion. A brief description of some investigations in these and other areas follows.

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Boundary-Layer Transition and Skin Friction

Basic to the aerodynamic heating problem is an understanding of the boundary layer flow conditions inasmuch as turbulent flow produces significantly higher heating rates than laminar flow. Skin friction drag, especially important in airplane design, is likewise considerably lower for laminar than turbulent flow. Consequently, several important investigations of transition have been undertaken.

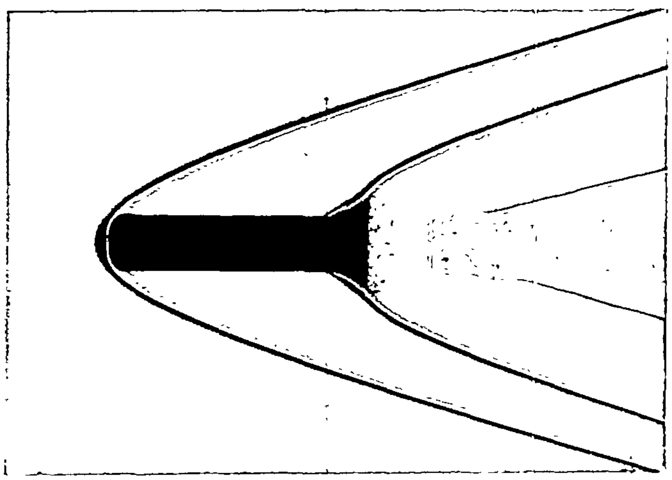
A study has been concluded concerned with the fundamental features of the transition process. Turbulence frequently begins in an unsteady fashion with an isolated burst of turbulence. Studies using a Mach-Zehnder interferometer were made of the shape, growth rates, and velocities of movement of such turbulent bursts at Mach numbers up to 7. Much progress has been made recently in wind-tunnel, flight and free-flight model tests in obtaining a better understanding of the effects of roughness on transition. Exploratory results first indicated that transition in most cases was caused by small roughnesses rather than inherent instability of the boundary layer. The limits, or conditions, in terms of basic boundary layer and roughness parameters, under which individual grains and bits of roughness will induce transition, have been clearly established for several basic shapes over an extended range of Reynolds and Mach numbers. Some of the roughness tests were made on blunt bodies. Both two-dimensional and three-dimensional roughness elements have been tested. If the roughness is below a certain critical height, it does not affect the skin friction drag perceptibly. Several investigations have been made for fully turbulent flow to study skin friction over a wide range of Mach and Reynolds numbers, boundary layer noise, and effects of high accelerations of a body on the flow.

It has been well established by tests in a number of facilities, including rocket model tests, that the effect of blunting the otherwise sharp leading edges of cones and flat plates is generally to move transition downstream. This effect has been explored up to Mach numbers of 10 and to very high Reynolds numbers. It has also been shown in recent years that moderate amounts of cooling tend to delay transition, although extreme cooling reverses this effect. Several research programs have yielded additional information on the phenomenon of "transition reversal due to overcooling" as may result when a body is heated rapidly on reentering the dense atmosphere. Perhaps the most important new result is that bluntness on some bodies may aggravate the reversal process, thus creating an interplay in the amount of nose or leading-edge bluntness to be incorporated from the opposing effects of reversal and theoretical transition delay due to bluntness.

Wing leading-edge sweep and shock interactions are known to promote early transition. Wind-tunnel and free-flight tests at Mach numbers up to 10 are continuing, including configurations appropriate for hypersonic boost-glide vehicles. One study has been directed at obtaining a better understanding of the flow mechanism at a sweptwing leading edge using an X-ray densitometer. Various flow visualization techniques have been developed for general transition experiments in both flight and wind-tunnel research.

Heat Transfer

Experimental studies of the aerodynamic heating of various shapes of blunt bodies applicable to reentering vehicles such as ballistic missile noses, hypersonic gliders, and satellites have been extended to higher temperatures, Reynolds numbers and to Mach numbers above 16 in some cases in flight, heated jets, wind tunnels, and shock tubes. Parallel theoretical work has firmy established analytical methods for calculating laminar heat transfer to basic blunt bodies, and both theory and experiments have shown the large reductions in heat transfer that can be obtained by making noses flatter or less convex. One series of tests indicated a slightly curved surface to have the lowest maximum heat rates as well as the lowest total heating rates of a number of bodies tested. Extension of the nose-flattening concept to concave bodies has been shown to have further promise if the flow can be kept steady. Some aerodynamic heating investigations have also been made in a high temperature jet and in flight at Mach numbers up to 14 to determine the effects of erosion, roughness, and depressions as might be inflicted on body noses by meteorites and flak. Exploratory studies have been made of erosion by ion bombardment using an ion beam apparatus.



Shadowgraph indicating heat-protecting shock wave generated at hypersonic speeds around gun-launched model of a blunt-nosed, flare-stabilized body.

Afterbody heating can also be a serious problem on reentering bodies. A principal controlling variable is the local air pressure. At low supersonic speeds the air pressure on a boattail afterbody is lower than free-stream pressure. However, tests at Mach numbers up to 14 have revealed that the afterbody pressure increased systematically with increasing Mach number and was several times the free-stream pressure at the highest speed. Base heat transfer measurements have been made on flared cone cylinder models and on surfaces submerged in the wake of forebodies.

Although much of the above basic body heat transfer research is pertinent to supersonic aircraft, hypersonic boost-glide, and other hypervelocity winged vehicles, considerable additional research has been accomplished on other heating problems of such vehicles. The wings of such vehicles are critical from a heating standpoint and most configurations have regions of flow interaction aggravating heating. Investigations have been made of the beneficial effect of wing leading-edge sweep in alleviating the heating. Some of the investigations have been of a fundamental nature using yawed cylinders at speeds up to 6,500 feet per second to assist in developing new compressibility theories. In other tests, complete model configurations with different amounts of leading-edge sweep have been investigated in hot jets, hypersonic wind tunnels, and flight at Mach numbers up to 14.5. In one basic investigation of the heat transfer at the body-wing juncture of hypersonic aircraft, a small heating increase was shown as compared to a flat plate reference value; in other cases large effects have been noted. Intensive studies of heat transfer to basic configurations are now underway in a number of facilities where juncture effects, together with leading-edge blunting, transition, and shock impingement effects are simultaneously assessed. New "thin skinned" model construction techniques have been developed to permit thermocouple installation for heat transfer measurements on more complicated configurations.

In many heat transfer investigations considerably more emphasis is now being placed on studying the important effects of angle of attack or yaw and pressure gradient. In one rocket model experiment rolling, the model was observed to have only a secondary effect on heat transfer. Analyses have been made of the heat transfer to a high Mach number ramjet engine and to subsonic and supersonic diffusers. It has been observed in wind-tunnel tests that a protuberance increases local heat transfer rates on the side of a model by large amounts.

Some research has been concerned with the flow of heat through separated boundary layers. Theory has predicted that the heat transfer through a separated laminar boundary layer is roughly half of that through an attached layer. On the other hand, theory suggested a greater heat transfer through a separated turbulent boundary layer than through an attached layer. Preliminary experiments have indicated that the theoretical prediction is correct for the laminar case but incorrect for the turbulent case, so that flow separation may have promise for reducing heat transfer in both laminar and turbulent flow.

Cooling

Many types of advanced reentry vehicles will more than likely utilize some form of reenforced cooling in critical areas to overcome the heating problem. A number of investigations are presently underway dealing with transpiration, film, internal and ablation cooling. The transpiration cooling process has been generally investigated in hot jets and wind tunnels with flat-plate models and with conical and flat-faced nose shapes as well as a porous cylindrical leading edge using helium primarily as a coolant. The effectiveness of helium transpiration cooling for body noses is also being investigated in flight. Film cooling by upstream injection of gaseous and liquid coolants is likewise being investigated in the same manner with various shaped bodies having conical, hemispherical, flat faced, inverse hemispherical, and other blunt noses.

One cooling technique for reentry vehicles receiving attention is underskin cooling by natural convection of liquids. Both theoretical and experimental programs are underway to determine the feasibility of such heat sinks. Models of double-walled structures are being used to investigate the effectiveness of convection cooling derived from the circulation of gases and liquids within the walls. The effects of vehicle rotation on the internal flow is also being evaluated.

Considerable effort has recently been expended in investigating the basic theoretical principles of ablation cooling. As a part of this work exploratory measurements have been made of the effective heats of ablation of a large number of materials and combinations of new materials in air jets at moderate to high heating rates. The ablation program includes flight tests of several models at Mach numbers above 14. Considerable effort has been expended in the development of suitable ablation rate sensors for flight application.

Air Properties at Elevated Temperatures

Flight at extreme hypersonic velocities and the accompanying high temperatures make it necessary ultimately to consider air as a real gas and not a perfect one. Thermodynamic and transport properties of air in the disturbed flow fields about hypervelocity vehicles can deviate widely from ideal gas values due to dissociation and ionization. As temperature increases, air becomes subject first to molecular vibration, then to dissociation of the oxygen molecules to form atomic oxygen and then to a similar dissociation of nitrogen molecules. An analytical study has been completed of the effect of oxygen vibration and dissociation in one-dimensional channel flow. The effects of the rates of the chemical and physical reactions were found to be appreciable. Theories for rates of reaction were found to be in serious disagreement indicating the need for experiments. A study has been made of the influence of the equilibrium chemical reaction in the air on expansion flows past corners termed Prandtl-Meyer flows. This type of flow has wide application in analyzing pressures on wings and bodies. The influence of the gas reactions was found to be subject to an exact analysis and the changes in flow properties were considerable.

Theoretical studies of air at extremely high temperatures have yielded approximate analytical expressions having considerable value in engineering applications in giving thermodynamic and transport properties of air that agree closely with those obtained by lengthy iteration methods.

Magnetogasdynamics

Ionization of air at high temperatures offers the possibility that airflow and hence heat transfer can be altered by application of magnetic fields about a body. The electrical conductivity of the high temperature gas at the nose of blunt bodies is appreciable during critical reentry conditions. Also, the conductivity may be increased by seeding the flow with easily ionizable materials such as the alkali metals. Such ideas have been theoretically explored and methods have been developed for permitting estimates of magnetohydrodynamic effects on heat transfer and skin friction to be made for cases hitherto unsolved.

Magnetogasdynamics opens a vitally important possibility of the generation and acceleration in the laboratory of high-velocity plasma flows that truly simulate hypersonic flight conditions. Considerable theoretical and experimental work is being accomplished on key problems, including electron diffusion, stability of plasma flows, boundary-layer flows in magnetic fields, rates of recombination of ions, and methods of ionization and electron emission. Arc jets and low-pressure seeded flows have been developed as ion sources.

There are indications that the conducting gas layer about a hypersonic vehicle may create a serious problem with regard to radio or telemeter transmission. Theoretical work has been carried out suggesting the use of magnetic fields to improve transmission. Radio transmission experiments are in progress using a cyanogen-oxygen flame seeded with potassium to simulate an ionized sheath about a body.

Body and Airfoil Flow Fields

An understanding of the basic flow fields around bodies and wings is fundamental to many design aspects of aircraft, missiles, and spacecraft. Several investigations of such nature have been completed or are in progress at all NACA laboratories throughout the speed spectrum. These include airfoil pressure distribution measurements, refinements in means of determining and reducing wave drag through area and moment-of-area rule principles, generalized theoretical studies of drag due to lift, generalized theoretical and experimental studies of body and wing-body flow fields at Mach numbers up to 10, and improvement of nose probe devices for measuring flow field characteristics.

Research Facilities and Techniques

An important part of the NACA's effort in basic fluid mechanics is continually devoted to exploring new techniques and apparatus in order that advanced facilities can be provided for research in the expanding frontiers of flight. Along these lines considerable progress has been made in the use of helium for high Mach number flows in wind tunnels. Advances have been made in tunnel-wall correction techniques. Work has continued in improving shock tubes to provide higher Mach numbers and stronger shocks. New shock tube and ultraviolet absorption techniques are being employed for studying air dissociation and recombination rates. Arc-powered wind tunnels and jets are likewise being developed to push the limits of their potentialities. Continued effort is being expended in improving the performance and utility of rocket free-flight test vehicles.

The combustion of cyanogen and oxygen yields CO and N_2 at a very high temperature suggesting a number of possible test uses which are being explored, for example, (1) heat transfer and ablation without chemical reaction, (2) chemical reaction effects and ablation by addition of contaminants to the hot flow, and (3) magnetohydrodynamics tests by seeding the flow with an alkali metal to obtain higher electrical conductivity. A low-velocity burner has been seeded with potassium and a supersonic jet is under construction.

A free-piston compressor has been put into operation in conjunction with a $M=11.2$ nozzle. The feasibility of using the thermal decomposition of nitrous oxide in the compressor has been demonstrated successfully. Nitrous oxide decomposes with the release of heat into nitrogen and oxygen in proportions closely simulating air. Whereas for air the theoretical final temperature for a typical case is 6,000° F., the nitrous oxide decomposition products raise the temperature to about 13,500° F. The compressor walls considerably lower these temperatures; nevertheless, indirect measurements have indicated temperatures greater than 5,000° F. using nitrous oxide.

HIGH-SPEED PERFORMANCE

All flight vehicles, whether an airplane, a missile, or a space vehicle that is to be recovered, must fly through the earth's atmosphere. Many aerodynamic problems must be overcome to accomplish this flight objective whether the vehicle is controlled by a human pilot or artificially. The aerodynamic characteristics of reentry vehicles are of such importance that the penalty for improper aerodynamic design is destruction. The NACA has conducted analytical and experimental studies to supply the information required for the solution of problems of atmospheric reentry. At the same time, work has continued on other problems of flight within the atmosphere. A very brief description of some of this work is contained in the following paragraphs.

Ballistic Missile, Satellite, and Spacecraft Configurations

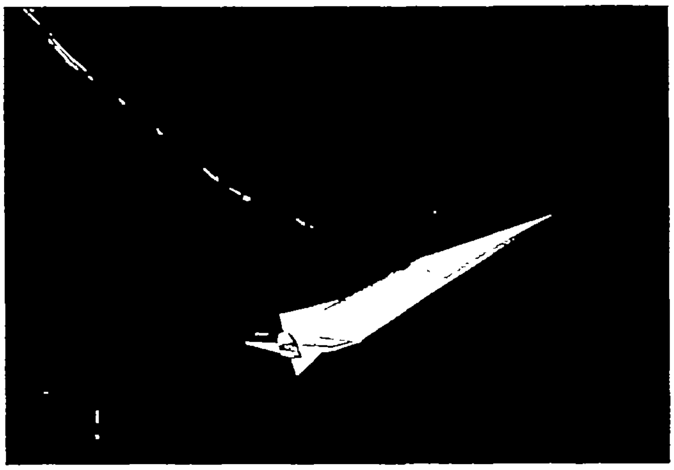
Broad analyses have been made of the heat transfer, atmosphere entry deceleration, and propulsion problems of vehicles for satellite, lunar, and interplanetary missions. Simplified equations have been developed by which a wide range of flight trajectories can be studied and important parameters varied so that designers can readily visualize trends, such as the effect of entry angle, speed, drag, and lift. The analyses included numerical calculation of the trajectories for round trips to the moon and the near planets using ranges of thrust-to-weight ratio and specific impulse typical of chemical rockets, nuclear rockets, and electric propulsion systems.

Proposals for manned satellites have been based on several design concepts such as high-drag blunt ballistic configurations, low-drag winged configurations, and combinations of the two utilizing small wings or body shaping to produce lift with high drag. The blunt wingless vehicles depend on a concept developed at the Ames Laboratory for the dissipation of heat due to aerodynamic heating. This is the concept that is used for the nose cones of present ballistic missiles. The winged vehicle utilizes lift to hold itself in the upper regions of the atmosphere while its speed is gradually reduced by drag forces; its heat is dissipated largely by radiation. The winged vehicle, being a glider after it enters the atmosphere, possesses the potential for some degree of control, thus providing a pilot with a choice of landing area. Ballistic high-drag vehicles would land by parachute, and a pilot would have virtually no control over the landing point once the vehicle entered the atmosphere. The low-lift, high-drag vehicle with small wings would also land by parachute, although some aerodynamic control can be provided to permit a pilot to make limited correction for errors in reentry angle or speed.

Studies of the many problems associated with these three types of vehicles are continuing. Research on reentry vehicles has been devoted to both blunt, nonlifting bodies of revolution applicable to ballistic missiles as well as reentering satellites and to body shapes which utilize lift in attempts to alleviate deceleration and aerodynamic heating problems. The high decelerations that are imposed on an occupant during reentry create a serious problem. Basic studies on methods of controlling decelerations and heat transfer of satellite vehicles and of predicting with reasonable accuracy the range covered during the return of the vehicle into the earth's atmosphere have been initiated. In one analytical study of the entry of a general class of high-drag vehicles having low-aspect-ratio wings, the deceleration, heating, and range were controlled by programing the angle of attack as a function of several measurable quantities such as initial flight-path angle and wing loading. Another theoretical and experimental study has been made of the stability and heat transfer to basic bodies of revolution shaped for minimum heat-transfer rates and suitable for ballistic missile or satellite use. The aerodynamic and heat-transfer characteristics of bodies employing lift during atmospheric entry are being studied, and a shape has been found which appears promising for manned satellites from the standpoint of aerodynamic heating, reentry deceleration, stability, and control. Some experimental investigations of the longitudinal characteristics of blunt, wingless reentry configurations at a Mach number of 7 have indicated that simple fins or flaps can provide satisfactory trim characteristics.

Another advanced flight concept that possesses aerodynamic problems akin to those of the winged satellite vehicle is the boost-glide vehicle, so named because of its mode of operation, which consists of rocket boost to its cruising speed and altitude and a powerless glide to its destination. Experimental and analytical studies have indicated the feasibility of the boost-glide flight concept and work has been conducted in the NACA Laboratories to provide solutions for many of the design problems.

Three main problems are the achievement of required lift-drag ratios, alleviation of the severe aerodynamic heating, and provision of satisfactory stability. Experimental and theoretical work is being conducted at all NACA Laboratories on the performance and stability of a number of boost-glide configurations. Wind-tunnel and rocket-model tests are being conducted to study the effects of body and wing planform geometry on the lift-drag characteristics at supersonic and hypersonic speeds. Aerodynamic heating, stability, and con-



Model of a hypersonic boost glide vehicle being flight tested in a wind tunnel to determine low speed dynamic stability characteristics during landing approach. Controls of the hydrogen-peroxide powered model are electrically activated by "pilots" outside tunnel through slack wires shown.

trol are also being studied over the anticipated operational Mach number and angle-of-attack range.

In addition to the reentry and glide phase of flight for these advanced flight concepts, there is the problem of launching the vehicles to the required speeds and altitudes. Some studies have been completed and others are continuing to provide information on booster vehicle staging, separation, aerodynamic loads, and stability.

Airplane Configurations

Although the program of research into space has been intensified, effort also has continued to improve the efficiency of flight within the atmosphere to the point where supersonic flight of fighter and research airplanes has become routine. Aerodynamic efficiency is improved by shaping the airframe to generate the required lift with the least possible drag. Propulsive efficiency requires that the air-breathing engine together with its intake and exhaust systems yield the greatest possible thrust for the lowest consumption of fuel. Structural efficiency seeks the lightest weight at greatest strength.

High-speed wind tunnels have been used advantageously to exploit the potential drag reductions suggested by supersonic wing theory. The benefits of sweepback have been systematically analyzed and new studies have revealed methods of accomplishing an elliptical distribution of lift over the wing surface which, in theory, would result in minimum drag due to lift. The advantages of cambering and twisting wings have been well established, and several supersonic airplanes now in operational use or in development incorporate these principles. However, the full potential of this approach as predicted by theory has not been realized in experiments and work is continuing on this problem. Friction drag is a major portion of the drag of supersonic and hypersonic aircraft as well as the source of aerodynamic heating. Research in this area has been pursued actively at all NACA research facilities.

New studies of interference pressure fields show promise in supersonic design application. By properly shaping an airplane the pressure fields resulting from interference between various airplane components can be made to react favorably to improve flight efficiency and stability. The study of the basic components of a vehicle and how these components can be combined is essential to understanding the problems and providing design information. Through the study of wings, bodies, and wing-body combinations, the feasibility of the advanced concepts and aircraft configurations described above has been established. Many of these fundamental studies have been conducted and are continuing. Considerable work has also been conducted on cockpit canopies with regard to shape and location on the fuselage. Improper design of the cockpit canopy can be a source of severe drag penalties.

Inlet problems, too, are of great importance in supersonic aircraft. Aside from the requirement of efficient inlets, it is necessary that the inlets be located so as to produce the lowest overall airplane drag. Research results have indicated that inlets can be located to alleviate interference adversely affecting flight efficiency.

In addition to the aerodynamic interference between the major components of aircraft, the interference of such elements as external stores, missiles, and nacelles can be important and have been studied. With regard to missile interference effects, the aircraft flow field can affect the missile-launching characteristics to the extent in some severe cases that the missile could collide with and destroy the parent aircraft. Considerable work has been done on the launching problem for both externally and internally carried stores and missiles.

INTERNAL FLOW

The performance characteristics of supersonic airplanes and missiles with air-breathing engines are strongly influenced by the overall efficiency of the engine induction and exhaust systems. The pressure recovery of these systems must be high to obtain both a maximum thrust for a given weight and a low rate of fuel consumption. The components must be shortened wherever possible to reduce weight. The overall drag must be kept small and the propulsion system must be capable of satisfactory operation at off-design conditions. During the past year considerable research has been conducted to determine methods for improving the performance of aircraft and missile internal flow systems. At Mach numbers up to 3, the research has been of a detailed nature, whereas at higher speeds the research is of a more exploratory nature to determine the problems which must be solved.

Inlets

Considerable research effort has been expended during the past year on inlet designs suitable for operation at high supersonic speeds. These tests have included all-internal contraction, external-internal contraction, and all-external contraction inlets. Methods investigated for improving performance over the operating range have consisted of boundary-layer control, variable geometry, airflow bypass, and location of the inlet in favorable airplane pressure fields. In addition, methods have been developed for maintaining high performance during angle-of-attack operation.

Several programs have been conducted in the area of inlet dynamics and the experimental results of an inlet-engine configuration have been correlated with a simple theory. Two inlet control systems were also evaluated and found to be effective in maintaining high inlet performance with varying flight and engine operating conditions.

A theoretical study has been concerned with the calculation of the external pressures on inlet cowls and the internal pressures in internal compression inlets designed to have isentropic compression. Comparison of a number of theories for computing the external pressure on inlet cowls has been made to assess their accuracy. Analytical studies have also been made to determine the effect of surface temperature on the properties of the boundary layer handled by an inlet scoop system. These results permit a prediction of boundary-layer-removal-system performance at high speeds.

Exploratory studies have been conducted on a variety of inlets designed for flight at hypersonic Mach numbers. These investigations permit a comparison of the performance of the basic types of inlets operating in this flight regime and indicate many of the design parameters which must be considered before efficient hypersonic flight can be obtained. Since flight at hypersonic speeds will require blunted inlet leading edges to reduce heat transfer and to facilitate cooling, an investigation was conducted at Mach 3 to determine the effects of such blunting on off-design performance.

Inlet designs for a number of specific engines and airplanes have been investigated and methods for obtaining improved performance from these designs have been found. Flight measurements with several military aircraft have also been made and the actual inlet operating characteristics determined.

Ducts and Diffusers

During the past year subsonic diffuser research has been concentrated on a study of the effects on pressure recovery and flow distortion of a diffuser operating with or without a normal shock near the throat. Boundary-layer shock interaction effects have been studied and the effects of boundary-layer control in a short diffuser are being determined.

A basic investigation of the characteristics of a turbulent boundary layer in a continuous adverse pressure gradient is also in progress to determine a method for minimizing boundary-layer effects in supersonic inlets.

Jet Exits

Several studies at transonic speeds have been made of the effects of jet exits on base and afterbody drag characteristics. A comprehensive investigation of clustered, multiple exits was included in this program, and the performance of several jet-exit configurations was determined. In addition, a family of divergent ejector nozzles was investigated to determine the off-design thrust levels that could be maintained, and a series of convergent-divergent exhaust nozzles were investigated to determine the separation characteristics at low-pressure ratios.

The interaction of the rocket nozzle flow and the external airstream in the base region of several ballistic missile configurations has received continued attention. Conditions for base burning and the general level of base temperature to be expected were determined for a number of configuration variables as well as for the basic prototypes.

Investigation of a method of varying the effective flow area of a convergent exhaust nozzle by aerodynamic means was conducted on an unheated-flow duct rig. Effective control was obtained and analytical expressions relating the performance with significant design and operating variables were developed.

Several model jet deflectors were investigated to determine the effects of design variables on their performance and operating characteristics. Transonic tests of the effects of a target-type thrust reverser have been conducted, while swiveled nozzles, auxiliary nozzles, and mechanical and aerodynamic deflectors which were designed to be adaptable to a wide variety of turbojet exhaust systems have been investigated in quiescent air. Analytical expressions relating the performance of each type deflector with significant design variables were also determined.

AERODYNAMIC STABILITY AND CONTROL

Stability

During the past year continued study has been made of factors affecting airplane pitchup—a longitudinal instability discomforting to the pilot and often dangerous. Detailed experimental studies were made to investigate methods for eliminating or alleviating the pitchup tendency; information was obtained on the effects of such modifications as changing the location of the horizontal tail and wing, of modifying the wing shape, and of adding auxiliary horizontal tails.

The problem of providing adequate but not excessive longitudinal stability over the complete speed range for high-performance airplanes has also received additional attention; this problem is of concern inasmuch as a very stable airplane will not only be difficult to maneuver but the large control deflections required for trim and maneuvering will result, especially at high speeds, in large loads, and high trim drag. Extensive wind-tunnel studies have been made to determine the static aerodynamic characteristics of canard configurations which have been found to have some advantages over conventional, tail-rearward designs. Analytical studies have been made to study the flight characteristics of a canard airplane having various amounts of longitudinal stability, and to investigate the need for automatic pitch-damping devices.

The loss of directional stability with increasing speed and angle of attack, characteristic of most supersonic airplanes, continues to be a design problem. Experimental model studies have been conducted which indicate the important influence of such factors as vertical tail and ventral fin size; wing planform, dihedral, and location; and fuselage nose length and cross-sectional shape. Guided by the results of such tests, theoretical methods have been developed which enable accurate design estimates of the directional stability characteristics of airplane configurations.

Accurate prediction of the dynamic stability characteristics of high-performance airplanes has also become of increasing importance to designers. Inasmuch as questions concerning dynamic stability can usually be resolved from a study of the rotary derivatives of a particular aircraft, increased attention has been given to obtaining information on these derivatives for a variety of configurations over a large angle-of-attack range. With these and other stability derivatives used as inputs into ground simulators, studies have been made of the ability of a pilot to control various airplane configurations under different flight conditions. Particular emphasis has been given to approximating the flight characteristics of the X–15 research airplane as fully as possible before its actual high-speed, high-altitude flights are initiated.

Although much of the information obtained in studies of conventional aircraft provide stability and control information applicable to very high-speed airplane and recoverable-satellite vehicles now being considered, additional and higher speed studies are required to determine the effect of the basic differences in such configurations on the aerodynamic characteristics. Extensive studies have been made on several hypersonic boost-glide designs to determine their stability and control characteristics over large speed ranges. Some of the models have been studies in free flight, simulating their characteristics in the low-speed, approach-to-landing flight condition, and providing information on the adequacy of the controls as well as on the possible need for artificial damping devices at these speeds. Analytical studies of the flight characteristics of such vehicles have also been made.

Experimental and analytical investigations to determine the stability and motion characteristics of configurations having lower lift-drag ratios considered more suitable for manned satellite or spacecraft during flight back into the earth's atmosphere have been initiated; the effects of fuselage nose blunting, stabilizing fins and flares, afterbody shape, and various types of controls have been studied experimentally. In addition to high-speed wind-tunnel studies to determine the basic stability and control characteristics of these configurations, low-speed information required to predict landing characteristics have been obtained. Analytical studies have been carried out with specific reference to the dynamic stability of a hypothetical manned vehicle which enters the atmosphere on a "skip-type" braking trajectory, executing an upward turn to eject itself from the atmosphere or to a less dense atmosphere to reenter at reduced speed. A general solution describing the dynamic stability and oscillatory characteristics of such vehicles following any trajectory has been developed.

The current importance of producing an effective long-range ballistic missile and of developing methods for combating them has resulted in an expansion of stability and control research in these areas. Experimental static and rotary derivative data have been obtained on a variety of configurations suitable for the warhead stage of the ballistic missile as well as for the previously mentioned studies of spacecraft entering the atmosphere. The effects of configuration changes, such as body-nose bluntness and afterbody shape, have been extensively investigated. These data, together with other calculated information, have been used in analytical studies to estimate the trajectory, stability, and aerodynamic heating during terminal descent.

Considerable effort has been devoted to the investigation of the supersonic aerodynamic characteristics of a series of missile models having configurations suitable for the interception of ballistic missile warheads. Various means of providing stability and control on tail-aft, canard, and flared-body models have been studied. Studies have also continued of the characteristics of more conventional, lower performance air-to-air, ground-to-air, ground-to-ground, and air-to-ground missiles.

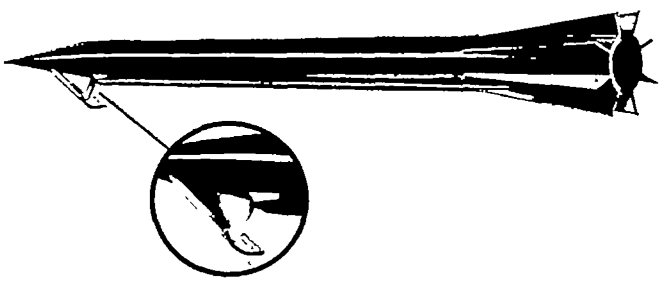
Controls

The increasing variety of airplane and missile configurations being designed has necessitated a broader knowledge of the characteristics of conventional controls and consideration of new concepts of control.

Wind-tunnel investigations have been made of such controls as flap and spoiler-slot deflectors, differentially deflected (rolling) tails, jet spoilers, and lateral blowing jets to determine the effects of various wing geometric parameters on the control characteristics. The effectiveness of the canard control surface, previously mentioned as being an attractive means of providing longitudinal trim for high-performance aircraft, has also been extensively studied.

Research has increased on jet-reaction controls having application to flight at very low speeds or high altitudes where aerodynamic controls have reduced effectiveness. One investigation has been made of the performance of a number of reaction control devices having possible application to the landing of VTOL aircraft and space vehicles. Analog studies have also been conducted to determine the effectiveness of reaction-jet controls similar to those to be used in flight tests of the X-15 research airplane.

Aerodynamic control systems intended for low aspect-ratio winged missiles have been studied over a range of supersonic Mach numbers; the relative effectiveness of tail, canard, swivel nose, and all-moving wing controls was determined. Other studies have been completed of the effectiveness of body-flap controls for air-launched, wingless missile configurations; such missiles require a minimum of stowage space and hence a minimum compromise of the drag characteristics of the missile-carrying aircraft. Body-flap controls have also been studied on missile configurations considered suitable for hypersonic antimissile use. In addition, basic studies have been made of vehicle control requirements for programing decelerations and heat transfer of vehicles reentering the atmosphere.



Model of a wingless air-to-air missile utilizing a retractable body flap as a lift-producing control device.

Flying Qualities

The flying qualities of airplanes designed to have very low or even negative static longitudinal stability at supersonic speed (in order to provide low trim drag and therefore increased range) have been studied recently. The limit of negative stability that can be tolerated, the effect of artificial pitch damping, and other factors affecting controllability were investigated from the standpoint of pilot opinion and measured performance using a pilot-controlled analog simulator.

Several projects to determine the acceptability of a side-located controller that requires an up-and-down hand motion pivoting at the wrist for longitudinal control and a lateral hand or forearm motion for lateral control have been undertaken. With this type of controller it is easier to restrain the pilot's arm so that high-acceleration levels will not introduce unwanted controller motions. Use of this type of controller also clears the center cockpit area which may then be used to good advantage for navigational instrument displays. Another fundamental flight research project was undertaken to determine the nature of such factors as pilot reaction time delay and response time in correcting airplane motions. Results of this research will aid in designing control systems to take best advantage of pilot capabilities. The results are also of value in determining the validity of other human-response tests conducted with ground simulators.

Investigation of the spin characteristics of models of many specific current and proposed military airplanes has continued utilizing the free-spinning tunnel. In some cases force data on the complete model or the fuselage nose alone have been required before proper interpretation of model spin-tunnel data could be made in terms of recovery characteristics for the corresponding airplane. The results show that recovery from the spin of some of the current-type fighters is so difficult that it would be very desirable to avoid entering fully developed spins. This can best be accomplished by determining the most expeditious way of recovery from the incipient phase of the spin. Preliminary tests have therefore been made to study methods of effecting such recovery on a scale model representing a current fighter airplane. A recently developed helicopter-launched, radio-controlled model technique has been utilized.

Flying quality research studies during the last year have also given additional consideration to the factors affecting pilot selection of landing-approach speed, Dutch-roll damping, and lateral-control requirements of several current fighter-type airplanes.

AUTOMATIC CONTROL

Missiles

Studies of missile stabilization and control have considered improved means of simplifying and analyzing complex automatic control and guidance devices. Although this program was initiated with reference to air-to-air attack missiles, the results have application to other classes of missiles, including ballistic and antiballistic, as well as to automatically controlled and guided airplanes. Some of these studies are discussed now.

Changes that occur in missile response characteristics to control deflections for varying flight conditions have led to complicated methods of adjusting automatic control parameters. In studying a number of simplifying techniques, consideration has been given to a control actuator whose torque output is proportional to the input of the control system. Results indicate that such actuators can simplify the control system and result in acceptable target-miss distances.

A study has been made to determine the relative importance of factors that place limitations on the minimum obtainable miss distance for a missile navigation system in which the missile follows a radar beam that is tracking the target. The factors considered were the natural motions, and steady-state acceleration capabilities of the missile, target evasive maneuvers, and radar angular scintillation noise. Simple correlation equations expressing minimum miss distance in terms of these factors were obtained. Possibilities for system improvements were indicated. Also studied were the effects on the average target-miss distance of limiting the allowable acceleration of a beam-rider missile. Contrary to intuitive thinking, the study showed that miss distance decreased as the ratio of the limiting to the design acceleration increased when the guidance system was designed for best performance at a given acceleration.

The determination of optimum radar-noise filtering characteristics to be used in weapon system design is generally a long and tedious process. Studies of these complex equations have been successful in determining simplifications and approximations to enable sufficiently accurate explicit solutions. From these results it has been possible to answer in a quantitative manner important questions regarding the effect of the target maneuver on the effectiveness of the guidance system.

Other work on improving missile systems indicated the need for enlarging the scope of filter theory to include nonlinear considerations. This is due to the trend of potential targets to fly at higher speeds and altitudes where the maneuverability advantage of the defensive missile is lost. Under these circumstances present theory is inadequate because the problem becomes a nonlinear one. A study was undertaken to generalize previous theory by exploiting the intentional use of nonlinearities as a means of minimizing miss distances.

Present theory dealing with noise contamination is restricted to systems whose design constants do not vary with time of flight. However, many systems have time-varying constants. Studies have been carried out to enlarge the scope of the theory so as to be applicable to these systems. Factors considered were target evasive maneuver, radar glint noise, missile maneuverability, and the inherent time-varying character of the missile maneuvers. The results of this and the preceding filter studies are applicable to many aircraft interception systems.

The problem of storing air-to-air missiles on parent airplanes has led to the consideration of wingless or very low aspect ratio missiles. These missiles rely on body-lift capabilities for maneuvering which require large pitch and yaw angles. The effects of these large angles on the performance of a navigation system was investigated analytically. It was shown that a problem requiring careful attention is space stabilization of the radar antenna against body motions.

Guidance and control requirements for antiballistic missiles have been investigated, considering both aerodynamic and reaction controls. Two types of interception were considered; one in which the relative-approach speed is small compared with the target speed, and the other where the relative-approach speeds are extremely large as would be associated with head-on interception. As part of this study, roll stabilization of hypersonic vehicles was investigated. Considered were the effects of large fuel expenditures and large dynamic pressure variations.

Aircraft and Spacecraft

Flight control studies of current high-performance airplanes and advanced airplane-design concepts have included ways and means of providing automatically stability and control characteristics acceptable to the human pilot for specific tasks such as landing and target tracking, and completely automatic flight-control where improved mission performance dictates.

Slow airplane response to various control commands such as roll, yaw, and throttle adversely affects the pilot's ability to control an airplane in landing approaches. Flight studies conducted in smooth and rough air with an airplane modified to provide artificial variation of roll and yaw damping have provided boundaries defining acceptable levels of damping and control response. Flight studies have also shown automatic throttle control to be a promising way of allowing reduced speeds in landing-approach maneuvers.

In many high-performance airplanes it is possible for the pilot to exceed inadvertently the design loads in accelerated and/or high angle-of-attack maneuvers. Analytical and ground simulator studies of an elevator-motion braking device actuated by normal acceleration, pitching acceleration, and pitching velocity signals were extended to flight. The flight studies indicate that inadvertent accelerations will be limited to tolerable levels.

Other studies have resulted in the development of a method of predicting the relative severity of pitchup and the effects of aerodynamic modifications and stability augmentation devices on several supersonic airplanes with pitchup problems. An automatic pitchup control system incorporating an angle-of-attack sensing device to retrim the horizontal stabilizer as the "pitchup region" is approached and entered has alleviated the pitchup considerably on a test airplane.

To increase the utilization of computer systems carried on aircraft, it has been thought that some functions need not be carried as continuous processes but could be handled intermittently on a time-sharing basis. Studies of yaw and pitch stabilization have led to the belief that discontinuous control systems could reduce complexity and system power requirements of airplane automatic control systems. A study has been made of the application of sampled-data theory to an airplane with an altitude control system. A better understanding of switching criteria has been obtained and should lead to useful design techniques.

On future airplane designs it may be necessary to tolerate marginal levels of static and/or dynamic stability for reasons of performance improvement and to obtain desired characteristics by stability augmentation. The problem of marginal flight control characteristics when the primary stability augmentation system fails has been studied to determine whether the pilot can cope with the emergency or whether secondary systems must be provided.

An airplane which can have its longitudinal dynamic response and control system characteristics varied has been utilized in a study of control system dynamics. Similar studies have been made on a ground-based simulator. Insight has been gained regarding the desired dynamics of longitudinal control systems for airplanes varying from transport types to those proposed for atmospheric entry vehicles.

Studies of airplane control systems where the pilot controls the airplane through commands to an automatic pilot were extended to take into consideration flight in rough air and flight at negative static stability margins as may be encountered at subsonic speeds by hypersonic designs. The systems involving angular-rate command and normal-acceleration command appear to be able to cope with small degrees of longitudinal instability.

The use of information derived from airborne radar equipment tracking a target at the end of a runway to assist in making an automatically controlled approach has been studied analytically. Such systems would eliminate the need for auxiliary ground equipment as employed in present landing control systems and make use of radar equipment already carried on many airplanes for other purposes. A usable airplane control scheme has been devised.

Flight and analytical research has continued on tracking control problems of current and projected interceptor airplanes. Studies included consideration of computer and radar display parameters for manual-mode tracking and study of factors that affect flight path stability and aiming accuracy in attacks with an automatically controlled interceptor, including consideration of system changes to improve performance against maneuvering targets. Studies were also made of the effects of high closing rates with consideration of the effects of interceptor maneuverability on guidance systems designed for interception in collision course attacks, and of an automatically controlled interceptor using bank-angle-error for lateral-control commands.

Piloting problems in exit and entry of manned flight from the atmosphere of the earth expose the pilot to an acceleration environment beyond his past experience. A joint NACA-contractor-military service program in support of the X-15 airplane program was conducted in a centrifuge to determine the effects of typical exit and entry acceleration time histories on pilots' ability to control the airplane. Specific factors considered were airplane stability augmentation and flight data presentation to the pilot. Other studies with hypersonic airplane type configurations have involved the use of a ground-based flight simulator to investigate damping requirements with regard to longitudinal, lateral-directional, and roll modes of motion.

Prediction of the dynamic behavior of large vehicles representative of ballistic missiles, hypersonic aircraft, or spacecraft during boost is complicated by the characteristic lightweight, flexible structure, and the large variable internal mass. In order to understand the stability and control problems of this class of vehicle, studies were undertaken considering autopilot and thrust control response, aerodynamic forces, fuel sloshing, and structural elasticity. These studies have given some insight to the problem of automatically stabilizing complete high-performance vehicle systems. Also the effects of reaction controls on the automatic stability control and orientation of these types of vehicles have been studied in the flight regimes where low air density makes conventional aerodynamic controls ineffective.

The flight dynamics of vehicles reentering the earth's atmosphere must be such that the vehicle does not exceed limiting attitude angles associated with aerodynamic heating and/or other structural considerations. Studies have been conducted to determine the degree of inherent aerodynamic or artificial stability required for typical bodies. Studies have also been made of the possible utilization of a man aboard a satellite for piloting purposes. Considered were flight-data instrumentation as well as vehicle stabilization and control requirements.

Preliminary considerations indicate that certain types of satellites will require accurate placement in orbit and accurate control of attitude. In a generalized investigation of satellite stabilization and control, consideration was given to such matters as the earth's force fields, internal power requirements and sources, control and sensing devices, and initial placement of the

Electronic Simulator Explores Piloting Problems

Cockpit in left background which is free to rotate in pitch and roll, coupled with electronic equipment in foreground, constitutes one of a number of flight simulators which enable study of piloting and control problems of high speed flight. In view of the safety and economy of simulators their use is becoming widespread.

satellite in the design orbit. The matter of attitude control was given special consideration. Control systems considered include hydrogen peroxide jets, inertia wheels, and permanent magnets that react with the magnetic field of the earth.

LOW-SPEED AERODYNAMICS

VTOL and STOL Aircraft

Emphasis in the field of VTOL and STOL aircraft has shifted somewhat from basic configuration studies to the broader problem of performance and stability of complete configurations. Dynamic models of two propeller-driven, tilt-wing experimental aircraft have been tested to determine the behavior of the aircraft during the transition from hovering to forward flight. Jet-powered models of the tilting-engine and tilting-wing-and-engine types have also been flown. Full-scale wind-tunnel tests of an unloaded rotor-type convertiplane have been made to investigate the vibration characteristics of the wing-pylon-rotor combination. In addition to free-flight model and wind-tunnel tests of VTOL and STOL aircraft, the NACA is becoming engaged in flight tests of test-bed VTOL/STOL aircraft to investigate handling qualities as well as stability and control characteristics.

Interest continues in a wide variety of VTOL/STOL applications involving both propellers and jet power plants. Recent investigations of a deflected slip-stream model showed that improved hovering efficiency is obtained when the number of propellers along the wingspan is increased, even when some overlapping of the propellers becomes necessary. The large amount of information now available on deflected slipstreams has been used as the basis for a semiempirical procedure for predicting lift and drag in transition of this type of vehicle.

Shrouded-propeller applications in the form of a stand-on aircraft and multiple-fan "flying jeeps" are also being investigated in model flight tests. These include investigation of the stability and control characteristics of two- and four-propeller arrangements in both shrouded and unshrouded configurations. A supporting program involves force tests of the same models. Initial flight tests with the two-propeller model showed that it required roll stabilization in hovering flight. As forward speed increased, increasing amounts of roll stabilization were required. The flight tests also showed that a greater angle of inclination was required to achieve a given forward speed than was anticipated.

Jet Flaps

Research on providing greater lift in order to improve the landing and takeoff performance of airplanes is continuing, with a significant portion of the effort directed toward the augmentation of lift by means of the jet-flap principle. Although some attention is still being given to refinement of methods of providing lift by suitable location of the jet exhaust on the wing profile and to the effect of flap span, increased emphasis is being placed on studies of the stability and control characteristics of complete configurations and on noise suppression possibilities of the various arrangements. In addition to low-speed wind-tunnel studies, free-flying models are being used to study the dynamic stability and control characteristics of jet-flap arrangements flying at high-lift coefficients. In these studies various methods of providing longitudinal trim and control are being used including downward-directed fuselage nose jets, jet-augmented flaps on canard surfaces, and various tail sizes and locations. Models of conventional jet-transport-type configurations with jet flaps have been flown at lift coefficients up to 12, using a nose jet for trimming.

Two other jet-flap areas receiving attention are cruise performance and the large loss of lift in ground effect. Research on the ground proximity problem is continuing in static wind-tunnel studies and is being extended to include takeoffs and landings with flying models. High-speed cruise performance studies have shown that the lift can be increased by blowing downward through closely spaced holes along and near the trailing edge.

Propellers

Among the several means of achieving VTOL operation of airplanes is the tilting propeller concept. Propeller data (performance and stress) are rather limited at high angles of attack. To attack the problem of obtaining full-scale propeller data under conditions typical of VTOL operation, a 3,000-horsepower tilting dynamometer has been put in operation, enabling the determination of isolated propeller characteristics under full-scale VTOL conditions in a wind tunnel. This includes operation at angles of attack up to 90°, corresponding to hovering and low-speed forward flight, and also at 180° corresponding to descending flight. The characteristics measured include not only conventional propeller coefficients but also levels of blade stresses encountered during the unconventional operating conditions. The first propeller type studied had flapping blades designed with the intention of alleviating the 1–P stresses encountered during high angle-of-attack operation and to permit a lighter propeller, although at the expense of a more complicated hub. In descent conditions the propeller had flapping instability introducing unacceptably large stresses.

Increasing interest in shrouded propellers for VTOL aircraft has prompted questions concerning their operation at zero forward speed and low forward speeds at high angles of attack. Performance, efficiency, and general design information is being gathered on a series of shrouded propellers from zero forward speed to high subsonic forward speeds, and from angles of attack from 0° to 90°. In addition, a systematic investigation has been started to determine the low-speed and hovering characteristics of shrouded propellers operating in the presence of wings and in the chord plane of wings.

An investigation of the aerodynamic characteristics of propellers designed for transonic forward speeds is essentially complete, utilizing a propeller research airplane. Three propellers were tested in conjunction with several spinners. Two propellers were designed for a forward Mach number of 0.95 and the third for a Mach number of 0.82. The first was a true supersonic propeller; the second a modified supersonic propeller; and the third, a transonic propeller. Efficiencies as high as 80 percent were measured at a forward Mach number 0.95 with the supersonic propellers. Minimum thickness-ratio distribution was determined to be the most important parameter in the design of propellers for transonic forward speed. Although all the propellers were noisy, the investigation indicated that supersonic propellers provide an attractive means of propulsion for long-range airplanes in which economy of operation, flexibility, and high static thrust are important.

SEAPLANES

Hydrodynamic research of both a basic and applied nature is progressing toward improving hydroski and hydrofoil development as well as seaplane configuration development having improved supersonic performance. At the same time a substantial amount of research has been initiated on underwater-launched missiles and on the water recovery or landing of manned spacecraft and hypersonic boost-glide vehicles.

Hydroskis

Fundamental research on hydroskis in the submerged and planing regimes has continued with the derivation of a unified method for calculating the lift of a rectangular flat plate in both regimes. Experimental investigations are likewise continuing on the effects of upper surface camber on a submerged surface and of longitudinal convexity on the bottom of a planing surface. Studies have been made of the characteristics of a submerged hydroski having a shape easily adaptable to practical construction methods, suitable means of reducing the spray of such elements during emergence and planing, and the influence of mutual wakes in multiple hydroski installations. Applications of the ski concept have been investigated on models of fighter aircraft, guided missiles as a recovery device, and hull-type seaplanes as a load-alleviating device.

Superactivating Hydrofoils

The new concept of using supercavitating hydrofoil sections on water-based aircraft elements to combat the adverse effects of high water speeds has been vigorously pursued both theoretically and experimentally. Analytical methods for dealing with ventilated as well as supercavitated flows, effects of aspect ratio, depth of submersion, and development of optimum sections have been derived and verified by model tests. Design charts to facilitate routine use of the theory have been devised. The physical process of ventilation is becoming better understood by the use of new methods to visualize the complex flows associated with this phenomenon. Attention is being given to practical application by investigation of structurally sound, surface-piercing arrangements such as highly tapered monoplanes, biplanes, and cascades with end plates. A specific application of two supercavitating hydrofoil systems is being investigated with a model of a full-scale test-bed airplane. The ability to accept highly cavitated flows at high water speeds gained in the research on hydrofoils has also led to investigation of supercavitating principles applied to underwater missiles.

Hull-Type Seaplanes

Research on hydrodynamic configurations and evaluations of advanced water-based aircraft concepts or preliminary design configurations has remained a substantial part of the hydrodynamic effort. With increasing interest in hydro-ski and hydrofoil solutions, the continued usefulness and versatility of the flying-boat hull have not been neglected. Experimental investigations have been continued in this area over a wide range of requirements from the very low landing speeds associated with antisubmarine warfare seaplanes to the very high landing speeds associated with supersonic attack aircraft. The configurations of interest have included those of large transonic transport aircraft, bomber aircraft, and small supersonic interceptor aircraft. In one series of tests of supersonic attack bomber-type configurations, attention has centered on means of obtaining spray clearance for air-breathing engine intakes and various hydrodynamic features for water takeoffs and landings. An investigation to determine the comparative rough-water capabilities of hulls, skis, and hydrofoils for such aircraft is also in progress.

Recovery of Spacecraft and Hypersonic Glide Vehicles

New horizons in the evolution of water-based aircraft have appeared in the form of manned hypersonic boost-glide vehicles and spacecraft which must be safely "ditched" or recovered after flight outside the atmosphere. Hydrodynamic investigations have accordingly been initiated of the water landing characteristics of typical satellite vehicles, including both high-drag winged and wingless reentry types. It is anticipated that through further research, the decelerations associated with water entry in favorable areas on the earth can be kept within reasonable human and structural tolerances.

Hydrodynamic Facilities

Investigation of the use of a small high-speed water jet to obtain fundamental hydrodynamic data has been completed. It was concluded that the use of a simple slotted boundary for such a jet reduced the boundary corrections on planing lift to a point where direct agreement with towing tank data could be obtained at high speeds for a wide range of test conditions. An improved towing carriage for the Langley high-speed hydrodynamic facility is being provided to increase the range of water speeds available by conventional tank procedures.

ROTARY WING AIRCRAFT

Performance

The extension of basic rotor theory in accordance with anticipated state-of-the-art changes has been a continuing process. Current efforts relate primarily to clarification of rotor force and blade-flapping phenomena for the severe flight conditions brought about by the considerable increases in installed power which are evident in new designs. This work utilizes published numerical procedures, in conjunction with electronic computers and full-scale experimental setups.

Limitations of helicopter speed due to retreating blade stall have been largely based on pilot reactions to roughness caused by the blade stall. A technique has been developed whereby the beginning of this blade stall can be detected readily under high forward-speed conditions. This is accomplished by monitoring blade-pitching moments and power input so that blade stall can occur to a measurable but not catastrophic degree. As a consequence, it has been possible to establish the allowable increase in forward speed for a rotor of a tandem helicopter resulting from a change in blade section from a symmetrical to a cambered section. A 20- to 25-percent increase in forward speed at the same weight or a 15-percent increase in gross weight appears possible.

Investigations are in progress to determine the static aerodynamic characteristics of helicopter rotors operating at tip speeds up to 900 fps. The effects of centrifugal forces on the rotor-blade boundary layer, tip flow field, and varying stall or compressibility areas over the rotor in forward flight are also being studied. Rotors having a wide range of blade-thickness ratios, thickness form, and leading-edge radius have been tested. These investigations have resulted in successful attempts to "synthesize" airfoil data from rotating rotor tests. Such data are expected to provide greater accuracy in the calculation of the forward flight characteristics of rotors operating at high tip speeds.

Vibration

As helicopters have become larger and more flexible, the magnitude of the vibrations associated with them has increased. The use of the helicopter for longer military missions and the increasing use of helicopters in civil applications have made the present vibration levels an increasingly serious matter. The designer is frequently unable to predict vibration sources and to provide methods of alleviation.

As a result of the increasing importance of this problem, a flight investigation was made to measure the vibration encountered by a specially equipped tandem helicopter. The first phase of the project involved the development of a method for measuring rotor blade, fuselage-coupled frequencies in flight. The technique involved the use of a mechanical shaker mounted in the helicopter. The results indicated that the method developed would provide a satisfactory means for flight testing of prototype helicopters for coupled frequency effects.

The project was extended to include the measurement of relative aerodynamic inputs for several flight conditions, of vibration effects due to blade out-of-track, and flight vibration mode shapes, through use of magnetic tape data recording. Vibration was only slightly increased when the blade out-of-track was less than 1 inch. However, as the out-of-track increased to slightly over 2 inches, the vibration became nearly intolerable. These efforts have not resulted in a state of knowledge which will permit satisfactory prediction and reduction of helicopter vibrations; however, use of the research technique holds promise for the attainment of this goal.

Stability and Control

Stability and control studies utilizing a variable-stability helicopter have succeeded in determining the degree of improvement attainable by increased damping and control power during instrument-flight landing approaches.

Low airspeed flights, including efforts to hover over a ground reference, have been conducted under simulated instrument conditions with a single-rotor helicopter having electronic autopilot-type components which permit alteration of the apparent (to the pilot) stability and control characteristics of the helicopter. By means of these components, systematic variations in such parameters as control power, damping in roll, yaw and pitch, stick force gradient and stabilization about each axis can be evaluated singly or in combination. The results confirm earlier work showing that improvements in handling qualities result with increases in damping. Also there is a large range of damping values within which desirable control powers are independent of the damping. However, as the damping is increased, the allowable maximum control power tends to increase.

A device that supplies signals to the pilot's instruments to indicate helicopter position and rate of change of position with respect to a ground reference, as well as helicopter altitude over the ground, has been constructed. The purpose of the device is to permit hovering on instruments so that handling qualities in hovering may be investigated. An additional device is also being constructed which will provide position and rate signals to the pilot in the form of stick forces.

Current efforts to assist in modernization of military flying qualities specifications for helicopters serve to emphasize both the value of the damping and control-power work completed and the need for more information; for example, how to apply the results established for helicopters of typical size to size extremes which can range from 250 to 100,000 pounds gross weight. As one step in learning possible effects of size, and also the effects of gross changes in the ratio of rotor inertia to aircraft inertia, brief tests have recently been completed with a tip-jet-driven helicopter of far smaller size but of higher relative rotor inertia than any previously tested. Certain beneficial effects related to high rotor inertia were readily apparent and led to additional comparative tests with more typical designs. Correlation of these results with those obtained with other larger helicopters is continuing.

POWERPLANTS

During the past year, the NACA increased its effort on studies of those powerplants believed to have potential as space propulsion systems and secondary power sources. The first results were presented at the NACA 1957 Flight Propulsion Conference, given at Cleveland in November 1957, 1 month after Sputnik I. This classified conference encompassed analyses of space missions, chemical propulsion systems, nuclear propulsion systems, electrical propulsion systems, auxiliary power systems, and propellants.

The conference also presented an NACA survey and assessment of air-breathing engines required for a "next generation" of airborne vehicles. Data, technology, research requirements and potential, with reference to turbojet and ramjet engines for flight from Mach 4 to Mach 18 were discussed.

SPACE PROPULSION

Analyses of satellite space vehicle problems and interplanetary space missions have been made. These analyses, while based on present knowledge and therefore very preliminary, have led to certain broad conclusions concerning the relative merits of various propulsion and auxiliary power systems and have helped to delineate the many areas of propulsion research that will be of increasing importance for space applications.

Auxiliary Electric Power

Systems using solar energy (solar batteries and solar turboelectric systems) involve the least weight for power requirements up to a few kilowatts, provided almost-continuous operation in the sun is possible. If only half time is spent in the sun, a number of systems are competitive, including radioisotope hydrogen-oxygen cells and radioisotope turboelectric systems. The nuclear turboelectric system without shielding is also competitive in this range of power, but shielding requirements, particularly for manned vehicles, may rule it out. Chemical batteries are competitive weightwise only for durations of operations of the order of a few days. The required voltage must also be considered in selecting auxiliary power systems. (Figs. 1 and 2.)

Satellite Sustainers and Orbit Control

For periods of operation of the order of 100 to 200 days or less, a low-thrust chemical rocket can provide the required propulsive energy without excessive weight penalty relative to electric systems. Particularly, if rapid orbit changes are required, the chemical rocket seems to be the only feasible propulsion system. For very long durations, or for permanent satellites, electric propulsion systems using solar energy or nuclear energy require less initial weight or resupply weight than chemical rockets.

Lunar and Mars Journeys

Many missions involving trips to the Moon and Mars can be accomplished without excessive weight penalty with high performance chemical rockets. These missions include one-way instrumented journeys to the Moon and Mars, and manned trips to the Moon. Electric propulsion systems seem undesirable for the Moon trip because of the long times required for the journey compared with those required for high-thrust rockets. For manned trips to Mars, however, electric propulsion

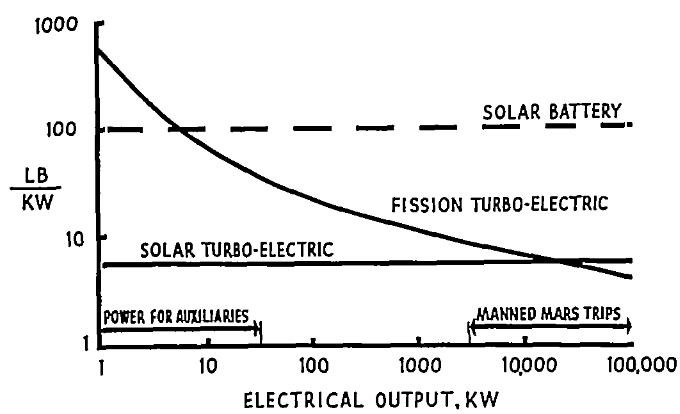


Figure 1.—**Weights for kilowatts of electrical power.**

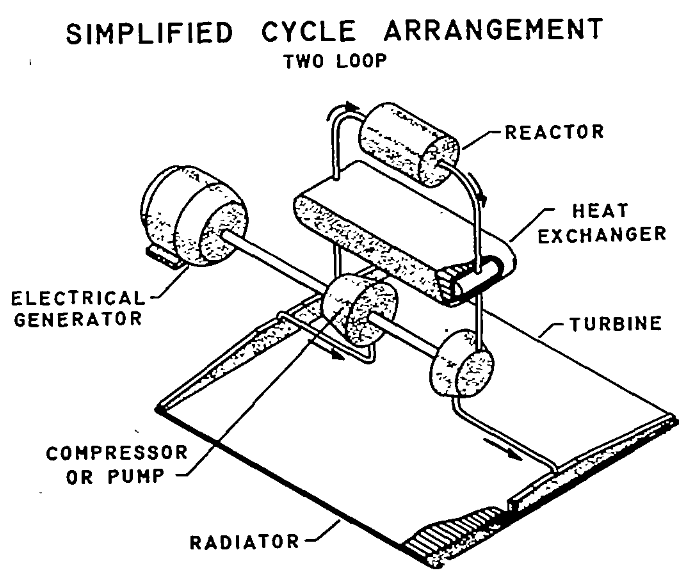
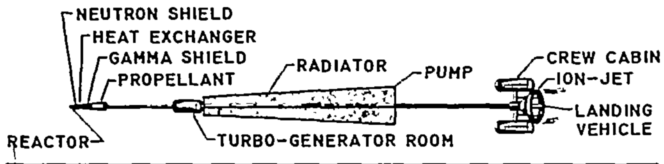


Figure 2.—**Auxiliary power from nuclear turbo-electric system.**

systems require only moderately more time for the complete journey than the chemical rocket, and their advantage in initial weight becomes greater and greater as the size of the expedition increases. Of the electric systems considered, the nuclear turboelectric, the solar turboelectric, and possibly the fusion-powered systems are capable of supplying the required electric power with sufficiently low weight. Of the thrust generators considered, the ion-electric accelerator appears to be most promising on the basis of current technology. (Fig. 3.)



PAYLOAD FOR 8 MAN CREW	LB		
10 LB/DAY/MAN	88,000	LENGTH	600 FT
CABINS	50,000	GROSS WT	322,000 LB
LANDING VEHICLE	40,000	POWERPLANT WT	60,400 LB
TOTAL	178,000	PROPELLANT	60,400 LB
		THRUST	32.2 LB
		POWER	11 MW

EXPLORATION TIME AT MARS, 329 DAYS
TOTAL ROUND TRIP TIME, 1100 DAYS

Figure 3.—**Electric spacecraft for round trip to Mars.**

The low-pressure, high-specific-impulse nuclear rocket is competitive with electric systems for large-scale Mars expeditions and has the advantage of higher thrust-weight ratio. It has the disadvantages that much higher temperatures are required than in the electric systems and that hydrogen must be used to attain the required high specific impulse. The latter requirement may impose severe storage difficulties for long-duration journeys.

Another advantage of the electric system over both the nuclear and chemical rockets is the resupply advantage. Since the electric system has the higher specific impulse, its propellant replacement weight is much less than that of the chemical and nuclear rockets.

PROPELLANTS

A continuing need exists for accurate and up-to-date theoretical performance data for a large number of rocket propellant combinations. A program for automatic computing equipment to permit calculation of the theoretical performance of any rocket or ramjet propellant has been set up. Calculations of the theoretical performance of many propellant combinations are kept up to date by a continual revision of the thermodynamic data necessary as various research organizations determine that data. (Fig. 4.)

Although the emphasis on rockets has grown considerably, work has continued on fuels for air-breathing engines, especially on the problems of applying the boron-hydride fuels.

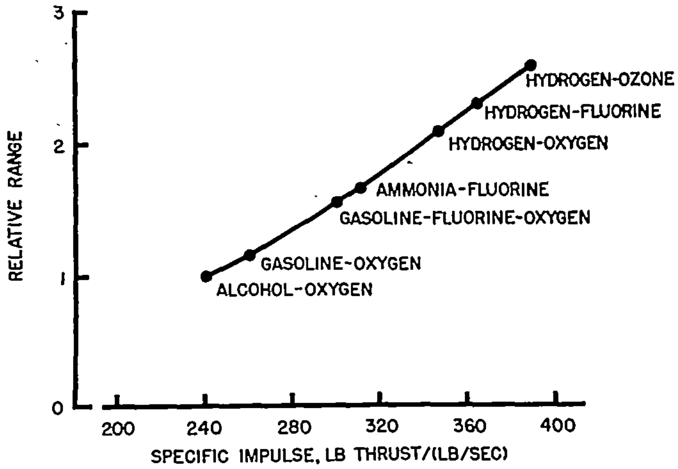


Figure 4.—**High energy fuels increase range.**

COMBUSTION

Combustion research has been directed toward studies of the vigorous combustion of high-energy fuel systems and rocket propellant combinations.

The value of gas analysis as a diagnostic tool for turbojet combustor research was demonstrated. It appears that the technique may also be of advantage in rocket research. In the turbojet combustor, estimates were made of local, rather than overall, fuel-air ratios, efficiencies, and heat release rates.

With the trend toward higher combustion temperatures that are associated with high-flight Mach numbers in air-breathing systems and with the use of rocket engines, studies of the physical chemistry of the burned gases are becoming more important. The rates of reaction and recombination in the burned gases are of special importance and are being studied. The effects of chemical reaction on heat transfer from combustion and other high-temperature gases are also under investigation.

Rocket combustion is a complex phenomenon involving many simultaneous physical and chemical processes. The rates of individual processes have been studied in order to predict overall performance in terms of the slowest rates. Detailed calculations of the evaporation rates of various rocket propellants have shown great promise for computing rocket performance, and a method relating the performance to the quantity of liquid propellant vaporized has been devised. The relation indicates that incomplete vaporization is responsible for combustor inefficiency.

COMPRESSORS

Over the past 15 years the results of research on compressors for turbojet engines have been reported in numerous publications. In the majority of instances, each of these reports presents only an incremental bit of information which taken by itself may appear to have only limited value. Taken altogether and properly correlated, however, this information represents significant advances in the design of axial flow compressors. The NACA, therefore, has compiled and assimilated into one report, virtually all of the advanced axial flow compressor technology.

During the past year, primary emphasis in compressor research has been on high-performance transonic and supersonic compressors for supersonic aircraft gas turbine engines.

A method was developed for the prediction of the off-design performance of axial-flow compressors. This method is consistent with a framework of equations and blade-element performance correlations commonly used in compressor design, and represents an attempt to provide a more general off-design performance prediction procedure than "stage-stacking" techniques which use assumed stage performance data. The performance of a rotating blade row was predicted, using this method, and compared with the experimental performance characteristics. At rotor-tip speeds that resulted in low relative inlet Mach numbers, computed performance was in good agreement with the experimental data. For high speeds, where the basic cascade data are not so applicable, a narrower satisfactory operating range was predicted than was obtained experimentally. It is believed that the discrepancies can be reduced by improvement of the estimation of high Mach number effects on blade-element performance.

PUMPS

A major part of the turbomachinery research effort has been directed at the problems of liquid pumps for rocket engine application. The objectives of this research are to increase operating limits of pumps, to reduce size and weight, and to provide pumps capable of operating with high-energy propellants. Initial research in this area involved the application of compressor design techniques to rocket pumps. The major problems were considered to fall into two categories: (1) cavitation, and (2) allowable loading (or velocity gradients) on pump blading. Fundamental research on the phenomenon of cavitation has been started, with emphasis on cryogenic fluids. In the category of blade-loading research, programs have been started on both centrifugal and axial-flow pumps, to establish blade-loading limits.

A study of flow-starting transients in a rocket was completed. A configuration consisting of a tank, suction line, constant speed pump (with bypass), variable flow-control valve, injector, and rocket chamber was analyzed theoretically. From this study, it was found that the time history of the main flow control has a decisive effect on the inlet pump head.

As part of the research program on pumping of cryogenics, a study was made of the conditions existing in a closed cryogenic container that typified a rocket propellant tank. This study showed that surface temperature controlled the pressure in a closed cryogenic container and verified the existence of temperature gradients in the liquid.

TURBINES

One phase of the turbine research program considered fundamental aspects of turbine design and performance. These studies are applicable to turbines for air-breathing engines as well as to turbodrives for rocket engines. As the culmination of some of this basic turbine research, an analysis (with substantiating experimental data) was made to establish turbine efficiency in terms of basic turbine design parameters for a range of turbine work and speed requirements and for various types of turbines.

A large part of the turbine research effort was directed at problems of turbodrives for rocket applications. These applications are characterized by very high work per pound of working fluid. The basic objectives of the research are to obtain high turbine efficiency, to reduce turbine size and weight, and to evolve turbines capable of operating in the working gases of rocket engines using advanced high-energy propellants. The initial phases of this turbodrive research included certain basic studies intended to establish research needs in the field. Analyses are being made to establish the effects of turbine-inlet temperature and turbine exhaust-gas thrust recovery on missile performance. A method was developed for determining turbine design characteristics for rocket turbodrive applications. A facility is being built to determine the effect on turbine performance of using cryogenic gases as the working fluid.

TURBINE COOLING

Turbine-coooling research was directed toward the study of air-cooled turbine blades that will be capable of operating at gas-temperature levels of 500° F. or more above those temperatures currently being employed in aircraft gas-turbine engines.

Research, using full-scale turbojet engines as test vehicles, was continued on shell-supported blades and strut-supported blades. The shell-supported blades offer very good heat-transfer characteristics and a relatively lightweight blade. Strut-supported blades offer very good heat-transfer characteristics but are heavier than shell-supported blades. Blades with porous shells for transpiration cooling were also investigated; such blades will theoretically cool more efficiently than other types of blades, but control of porosity and the obtaining of sufficient strength in the porous material are major problems. (Fig. 5.)

Figure 5.—**Transpiration cooled blade.**

Special studies of the cooling problems in the leading-edge regions of cooled turbine blades were inaugurated by investigating the cooling of small airfoils in a tunnel capable of operating at gas temperatures up to 3,000° F.

A special engine incorporating an air-cooled turbine stator and rotor for making full-scale engine investigations under actual high-temperature operating conditions is being prepared for operation. In order to provide turbine blades for this engine, it was necessary first to investigate a number of problems such as brazing techniques, effect of brazing on material strength, attachment of blade shell to blade base, and heat treatment, that are associated with air-cooled turbine blades. These problems have now been resolved, and a set of cooled blades for the engine has been fabricated and is now being instrumented prior to installation in the engine for research purposes.

An analysis of heat transfer and flow in boundary layers with variable fluid properties in the entrance region of smooth tubes and flat plates was completed. Also completed was an analysis on the effect of variable fluid properties on free convection, and an analytical and experimental study of laminar heat transfer in a vertical circular tube under combined forced and free convection. A new method for measuring residual stresses in disks was devised and analytically confirmed.

ENGINE CONTROLS

Emphasis on control research has been directed toward rocket engines, together with initial explorations of nuclear rocket and other space propulsion systems. Research is underway on rocket fuel systems with respect to such items as the dynamic characteristics of long hydraulic lines, dynamics of centrifugal pumps, combustion chamber pressure control, and propellant mixture ratio control. A study of the requirements of rocket engines and reaction devices for control of the trajectory of missiles has been initiated.

A major effort is being expended in an attempt to correlate analytical expressions for the dynamics of rocket components and for rates of propellant vaporization with experimentally observed liquid propellant rocket motor instability. The ultimate goal in this work is to permit accurate prediction of rocket instability and to determine design criteria for rocket scaling and for development of variable thrust rocket motors.

An analysis of control requirements for nuclear turbojet propulsion systems was initiated. System components were analyzed, reactor kinetics were simulated on an analog computer, and nuclear reactivity was determined.

The dynamic response of supersonic diffusers to disturbances in downstream conditions was analyzed. The analysis included the shock motion in the diffuser as a function of downstream pressure disturbances, and the response of subsonic diffuser pressures to disturbances in fuel flow for ramjet engines. The analysis relates the various dynamics to the particular operating conditions and to the physical dimensions of the system considered, and thereby makes possible control design prior to physical testing of the system.

Turbojet engine performance was investigated experimentally with several configurations of interacting multiple loop controls to determine the mode of control required for obtaining optimum rotor speed and turbine discharge temperature transient response characteristics during (1) thrust increase and (2) afterburner ignition, with manipulation of engine fuel flow and exhaust nozzle area. Good engine transient performance, near the design point, was obtained with a control system in which engine speed was controlled by exhaust nozzle area and the turbine-discharge temperature was controlled by manipulation of the engine fuel flow.

POWERPLANT MATERIALS

High Temperature Alloys

Despite the extensive test work done in the past which has established good correlations between stress-rupture data in the laboratory and service life in engines, several questions have remained unanswered. One concerns the effect of "overtemperature" operation on the life of turbine blades. Since the stress-rupture life of the material may be shortened by overtemperature in a stress-rupture test, does it follow that engine life is affected by overtemperature operation? Does reheat treating the blades help?

To answer these questions, a recent study was made of S–816 (a cobalt-base alloy) blades overtemperatured in J–47 engines. An example of one of the conditions of overtemperature encountered was engine overspeed by 4 percent, with tailpipe temperature about 200° F. over normal, for an unknown period of time. These blades were removed from service and tested in a laboratory J–47 engine under repeated cycles of 15 minutes rated and 5 minutes idle speeds. Stress-rupture tests and metallographic examinations were made in an attempt to correlate properties and microstructure with engine results.

It was found that overtemperatured buckets did not fracture in service in abnormally short operating times. Cracking, particularly on the leading edge, was the principle mode of failure of buckets. Although cracks developed after short operating times, they did not propagate to fracture during several hundred hours of operation. The overtemperatured buckets failed in stress-rupture tests in shorter periods of time than buckets directly from stock and also failed in shorter periods of time than the overtemperatured buckets which had been subsequently heat treated. In fact, full reheat treatment of overtemperatured buckets, using the standard heat treatment, increased the resistance of the blades to leading edge cracking and also improved the stress-rupture life of the material. Such buckets performed both in the engine and in stress-rupture tests equivalently to new standard buckets.

A laboratory investigation of overheating indicates the complexity of the high-temperature alloy studies. In this investigation, periodic overheats were conducted at temperatures to 2,000° F. both with no stress and with stress present. (No engine tests were performed.) The alloy studied was a nickel-base alloy, M–252. It was found that periodic 2-minute overheats to 1,900° or 2,000° F. very substantially increased the rupture time of M–252 alloy at 1,500° F., provided no stress was present during overheat. Such overheating was damaging only if a sufficient high stress were present to use up a significant proportion of total rupture life. However, when M–252 alloy is repeatedly overheated to 1,650° and 1,800° F. in the absence of stress, the rupture life at 1,500° F. is reduced. In the presence of stress, however, the damage is less than anticipated. Consequently, if stress is present it must be quite high to do any significant damage.

Physics of Solids

The aim of the physics of solids research is to provide basic knowledge to aid in the development of materials for use at very high temperatures and in chemically active atmospheres. Among the problems under study are the chemical reaction of materials in certain environments which may be affected by nuclear reactor design, aerodynamic heating, and flight in the upper atmosphere.

Platinum has long been known as an inert metal; in fact, it has been the standard crucible material used in chemical analysis bceause of its resistance to oxidation and direct flames and its resistance to attack by rather active chemicals. Previous studies of the rates of oxidation of platinum at temperatures to 1,400° C. in molecular oxygen have indicated a very low oxidation rate. However, recent studies conducted at these temperatures and at pressures below 0.1 millimeter of mercury have indicated a very marked increase in oxidation rate at low pressures. These results appear contradictory when one considers the pressure of a gas is a measure of the concentration of the gas. However, the studies have been conclusive and indicate that previously observed rates under relatively static conditions may be in error when dynamic conditions, namely free motion of the gases, is present. At pressures above 0.1 millimeter of mercury, oxidation is strongly inhibited by back reflection from the gas.

LUBRICATION AND WEAR

Bearing Research

In recent years the statistical design of experiments has found favor as a device for planning experimental research. Many factors which affect the course and results of an experiment can be varied simultaneously and their effects separately and concurrently analyzed. However, with phenomena such as the fatigue failure of bearings, which are so complex and have so many factors contributing to or alleviating failure, statistical design has not been successful. Therefore, it has been necessary to return to the classical experimental method of studying one variable at a time in order to make any progress in the study of bearing failure.

Tests are performed on a rolling contact fatigue spin rig where balls are rolled around the inside of a cylinder by the action of compressed-air jets. Previous studies of the rig had indicated similar patterns of failure and fatigue lives on the balls in comparison with those obtained in actual bearings. In addition, the number of test variables is reduced.

One research area which appears very promising is the study of the metallographic structure of balls and races as a clue to variable bearing life. Balls and races are made of steel which has been forged or rolled so that it has a definite crystal orientation. This orientation shows up on etching a cross section and is usually referred to as fiber. It has been found recently that if the fibers are not oriented parallel to the axis of the cylinder (which corresponds to the outer race of a bearing), the fatigue life of the cylinder is drastically reduced.

In this investigation, cylinders were prepared in three groups from forged stock. In the first group, the cylinders had their axes parallel to the fibers of the steel stock. In another group the fiber was arranged so that it was from 0° to 45° to the axis of the cylinder, and in a third group the axis of the cylinder was at 0° to 90° from the fiber of the material. When comparing the data obtained on these cylinders, it was evident that by using material whose fiber was parallel to the surface of the cylinder, a large increase in life of the cylinders was obtained. For example, in this series of tests only 10 percent of the cylinders with surfaces parallel to the fiber of the material had failed by 5 million cycles. By 60 million stress cycles, 80 percent of the cylinders had failed. However, with cylinders oriented from 81° to 90° to the fiber, 10 percent of the failures has been obtained by 1¼ million stress cycles and 80 percent by 3 million stress cycles. We thus see a profound effect of fiber orientation both on the first failures and on all failures. The study of the relation of failure to fiber orientation in balls is considerably more complex since fiber orientation can be determined only after the balls have been tested. However, the striking relationship of fiber orientation to ball failure is also illustrated by a polar projection of failure incidences versus fiber orientation. (Fig. 6.)

NUCLEAR PROPULSION

The NACA nuclear research program has been directed toward solving the problems associated with the application of nuclear power to the propulsion of aircraft and rockets. Analytical studies have been and are being carried out on nuclear aircraft propulsion systems, nuclear booster-rocket systems, nuclear heat-transfer, interplanetary propulsion systems, and nuclear electric-generating systems for space-travel application. These studies have been specifically directed toward defining the research problems that must be solved in order to achieve the potential indicated for these various systems.

The construction of reactor facilities to be used in conducting experimental nuclear research studies is continuing. The construction of the low-power, solution-type research reactor located at Lewis has been completed. Work is continuing on the Plum Brook

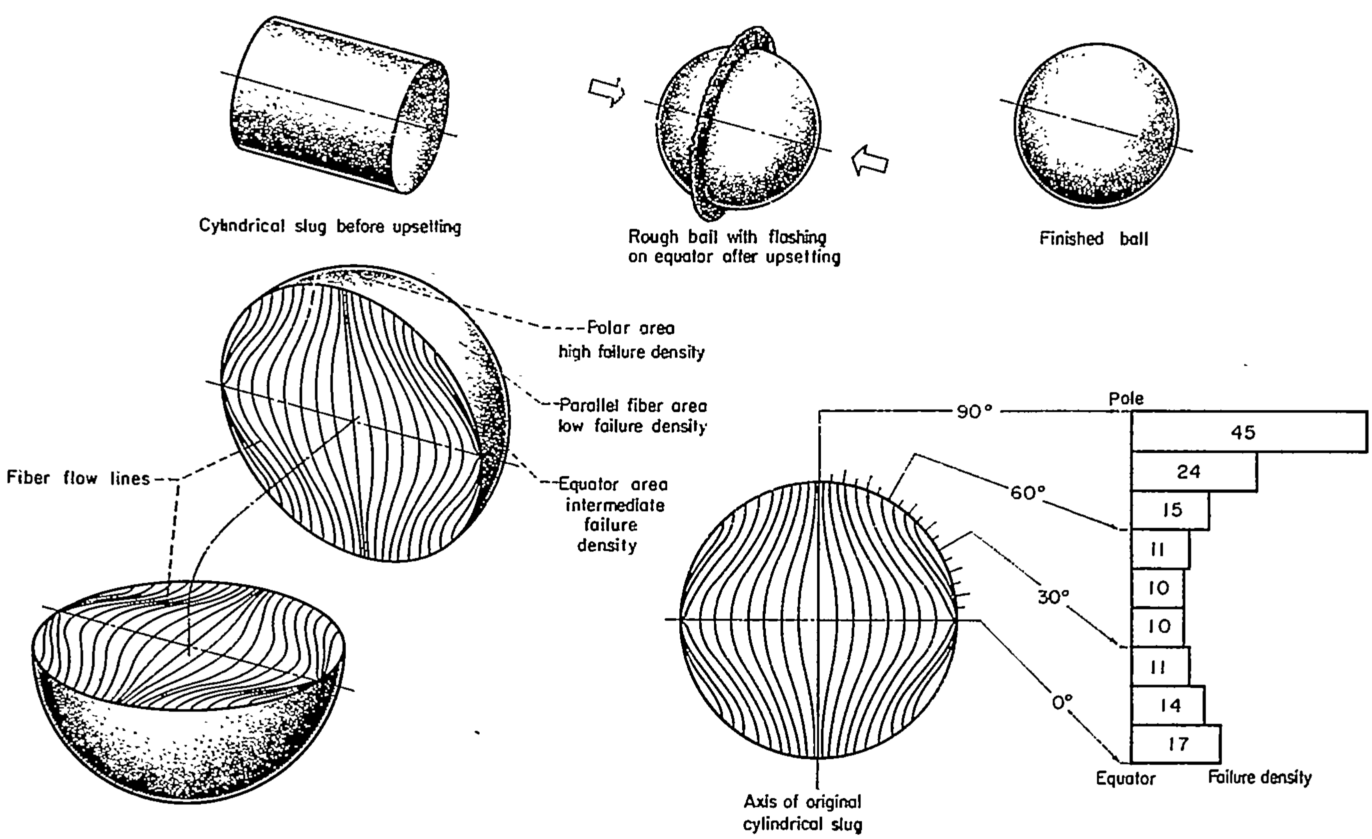


Figure 6.—Susceptibility to fatigue failure in bearing balls as influenced by forging fiber orientation.

Reactor Facility. Experiments applicable to space-flight systems are being planned and designed for both of these facilities.

Methods have been devised for evaluating weights of shields for aircraft and rocket systems. Studies of various methods of shield design, including the statistical methods, are continuing. Equipment is being fabricated to study the attenuation of gamma photons in various shield materials and also to study the gamma ray streaming through ducts in shields.

The effort on reactor analysis has been devoted to studies of reactors for jet engine propulsion systems and various rocket systems in order to determine effects of core size, composition, reflector thickness and material, moderator material, and fuel-element material on uranium requirements, and flux and power distributions. Analyses and experiments are being conducted to develop methods of predicting nuclear characteristics of reactors of unusual or complex geometry for space-flight systems.

A number of heat-transfer and flow problems associated with nuclear powerplants are being studied. This work is intended to provide pertinent information of a fundamental nature that will be of general usefulness in the development of various types of nuclear propulsion systems.

Sodium hydroxide is in many ways an attractive choice as a high-temperature, heat-transfer fluid. Unfortunately, only a few materials are suitable for containing it in the molten condition at temperatures of 1,500° to 1,700° F. Among these are nickel, copper, silver, gold, and some nickel-base alloys. Even these materials exhibit a form of corrosion termed "thermal-gradient mass transfer." Thermal-gradient mass transfer is the phenomenon by which the container metal is removed (either chemically or physically) from the hotter regions of a system and deposited in colder regions by the heat transfer fluid. With the previously listed metals the deposit is in the form of needlelike crystals, the size of which depend upon the experimental conditions. (Fig. 7.)

In order to find ways of inhibiting this type of corrosion, an investigation was conducted concerning the possible mechanisms. The mechanisms were found to depend on chemical reactions between hot and cold zones and molecular diffusion within each zone.

The diffusion of the molecular species in the melt will allow the process to continue indefinitely. In dynamic tests, the rate of transfer is controlled by the rate of the zone reactions and thus is constant with time. In static tests, the rate of transfer is controlled by the rate of diffusion and increases with time.

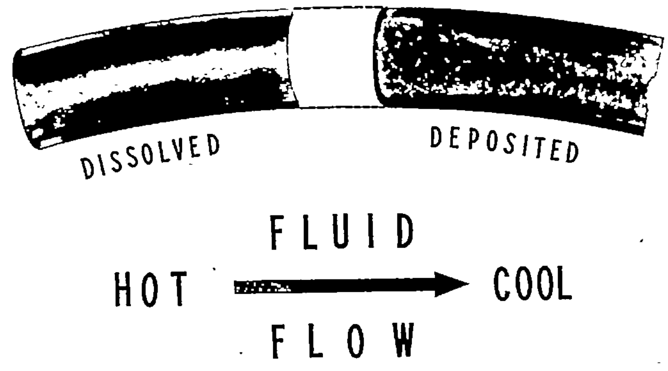


Figure 7.—Mass transfer of structural materials by a coolant.

The effects of additives upon the rate of transfer were also explained. Additives which effectively increased the sodium oxide concentration increase the rate of transfer; those which decrease this concentration decrease the rate of transfer. Reducing agents decrease the rate of transfer in static tests and have no effect in dynamic tests. Oxidizing agents have the opposite effect in static tests.

Experiments are being set up on the 60-inch cyclotron to study the heat-transfer characteristics of ionized gases and also to study the range of fission fragments in ionized gases. Such studies are directly applicable to the space nuclear-propulsion systems now being evaluated.

A two-dimensional diffusion theory has been developed for determination of reactivity effects of a fuel-plate-removal experiment. This and other diffusion theory analyses are being checked experimentally by duplicating the essential neutron-diffusion phenomena with a point source of fast neutrons.

Heat-transfer characteristics of liquid metals flowing over a flat plate were analyzed using laminar boundary-layer equations. Numerical solutions of the appropriate differential equations were carried for the situation of uniform wall temperature and uniform wall heat flux.

Laminar free convection from a vertical flat plate with nonuniform surface temperature was analyzed. Analyses of transient forced-convection flow and heat transfer, and of effects of internal heat sources on forced convection in ducts were completed.

AIRCRAFT, MISSILE, AND SPACECRAFT CONSTRUCTION

It is in the field of construction that the designers' ideas are translated into structure or "hardware" which will possess the serviceability and structural integrity necessary to attain the desired vehicle mission.

The operation of hypersonic aircraft and missiles and the venturing into space raise many new problems with regard to structural design, materials, and influences of environment for which solutions are actively being sought. A great deal of attention has been required in the way of defining new problems and developing new facilities.

STRUCTURES

Structures research during the past year has been directed primarily to the problems of aerodynamic heating, with particular attention being focused upon the problems associated with hypersonic gliders and various types of reentry vehicles. Consideration was also given to the structural problems of space vehicles, and some fundamental structural studies were reoriented in this direction.

The types of structural configurations suitable for hypersonic boost-glide aircraft and orbital reentry vehicles were investigated. Comparisons were made of the various structural approaches such as the use of unprotected structures, heat sink structures, insulation, cooling, and ablation. The successful use of unprotected structures is dependent on development and improvement of refractory metals, whereas insulated and cooled structures may be developed using existing materials. Research on insulation and cooling has included experimental and theoretical studies of the effectiveness of gas coolants in the passages of corrugated core sandwiches, investigations of the feasibility of using built-up ceramic coatings as thermal shields, and simple methods of providing coolant as an integral, noncirculating part of sandwich construction. The optimum combination of insulation with various types of structural elements has been studied theoretically, and structural integrity tests have been made on several types of thermal shields and insulating panels.

The thermal stresses induced in structures by transient aerodynamic heating can have adverse effects on their strength and stiffness. Theoretical and experimental studies of these effects have been conducted for various structural configurations. Experimental studies of the effect of thermal stress on the buckling and ultimate strength of ring stiffened cylinders and multiweb beams have continued. Additional data have been obtained on the combination of compressive, shear, and thermal stresses that cause permanent buckling of plates. An analytical determination of the minimum weight of a multiweb beam subjected to combined bending and thermal stress is nearing completion.

A reasonably accurate knowledge of the temperature distribution in a structure is a prerequisite to all elevated temperature structural analyses. The relative importance of heat transfer by conduction, convection, and radiation in sandwich panels was studied and an approximate procedure for estimating radiation effects was devised.

A program for the development of several basic type insulating structures is currently in progress. The structures as conceived are applicable to hypersonic vehicles and manned satellites, and are capable of extended operation with wall temperatures in the range from 1,500° to 2,500° F. Conventional metals as well as materials such as graphite have been used for the outer walls, and fibrous materials have been employed as insulators. Tests of some specimens have been conducted in radiant heater and hot-jet facilities with promising results.

Creep of structures at high temperatures can lead to large deformations and premature failures. Data have been obtained on the creep behavior of stainless-steel plates at temperatures from 700° to 1,000° F., and on the creep behavior of built-up structures such as box beams and unstiffened cylinders.

If all of the complex interactions between aerodynamic heating and loading are to be studied, it is essential that some structural testing be done in an aerodynamic environment. Work of this type was initiated several years ago, using small facilities and has continued during the past year. A new facility, the 9- by 6-foot Thermal Structures Tunnel, was put into operation during the past year. This facility can produce a Mach 3 airstream with a stagnation pressure of 200 psi and a stagnation temperature of 660° F. This facility affords testing of structures under realistic aerodynamic and thermal conditions.

Accurate methods of deflection analysis are essential to the determination of the response of structures to dynamic loads. Studies of structural dynamics included the vibration characteristics of an integrally stiffened 60° delta wing, secondary effects in the vibration of monocoque beams, and a comparative analysis of the accuracy of several methods for calculating transient

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The 9- by 6-foot thermal structures tunnel.

response. A blast simulator apparatus is being used to study the failure of multiweb beams subjected to very short time, high-intensity loadings.

The problem of designing a structure of minimum weight and of the desired strength at room and elevated temperatures is basic to all aircraft and missile designs, and requires continued research if the performance goals of future vehicles are to be achieved. Sandwich construction is the most probable configuration for efficient utilization of high density and refractory metals in high-speed vehicles; consequently, research on sandwich construction is continuing and has included analytical studies of the local instability of the elements of truss-core sandwiches, tests of sandwich elements, plates and beams at room temperatures, and crippling tests of shell sandwich construction at temperatures up to 1,200° F. with temperature gradients through the thickness. Investigations of sandwich materials suitable for use in the 2,000° to 2,500° F. range have been initiated.

Cylindrical and conical shell structures find extensive use in long-range missiles and space vehicles, but many configurations are in a range where theory is inadequate and data are scarce. The work in this area has been intensified to determine th cause of the deficiencies of present theoretical methods and to formulate new shell theories. Experimental work is also in progress to determine the strength of longitudinally stiffened curved sheet and of ring-stiffened cylinders.

Fatigue problems continue to be a major factor in the operation of many civilian and military aircraft. Recent investigation of the fatigue of structures has been principally concerned with the fail-safe design approach. Structures designed under this approach can tolerate appreciable damage by fatigue cracks without suffering catastrophic failure. During the past year tests have been continued on panels and box beams to better understand the factors affecting fatigue crack growth and the reduction in static strength resulting from cracks. Tests of full-scale airplane wings have been continued to provide information on their resistance to fatigue.

LOADS

The effort devoted to various phases of loads research continues to change because parameters important to structural design such as airspeed, range, structural flexibility, ratio of payload to total weight, heat transfer into the structure, and control inputs continue to vary over wide limits. Accordingly, increasing emphasis is being placed on the theoretical and analytical methods for predicting effects of these variables and on methods for analyzing experimental data so as to permit generalization of results.

Because of the high rate of fuel consumption and the wide range in altitude that is rapidly traversed in some aircraft operations, it is becoming increasingly important to account for fuel consumption, air density, etc., as function of time rather than handling these quantities as constant for short time periods. Studies have shown that it is practicable to extend existing analytical procedures to account for these additional complexities.

The manner in which the newer types of aircraft and spacecraft will be operated is expected to change so radically from present-day operation that philosophies of structural design which are based on past experience in the low-speed range will be outmoded; as a result, various types of craft having differing missions are being studied to determine how present structural load requirements must be modified to place the design of such craft on a more rational basis.

The problems concerned with the effects of flexibility on the loads and structural strains experienced by an airplane in rough air are becoming increasingly important because of the higher flight speeds and the use of thin sweptback wings. A flight investigation of structural response showed large amplifications in the structural strains and wing deformations. The strain amplification factor measured during rough air flights varied from 10 to 20 percent at the wing root to values in excess of 100 percent at the midspan station. The major source of aerodynamic forces that are developed in rough air are due to wing structural deflection and twisting, particularly at frequencies corresponding to the first wing-bending mode.

In order to obtain turbulence data which may be used in synthesizing the gust histories for a wide variety of operations, the airline gust data collection programs have been supplemented with projects aimed at establishing the turbulence characteristics for particular flight conditions. Among these conditions are the very low altitudes (below 1,000 feet), high-speed flight, and the more severe weather disturbances represented by hurricanes or tornadoes. The very low altitude data have been derived primarily from tower measurements, while results for other weather conditions are being obtained from cooperative flight tests with the Air Force, Weather Bureau, and Navy. In addition to determining the intensity of the turbulence for direct application to airplane and missile operations, effort is also being made to establish the significant meteorological parameters associated with the turbulence.

Rocket-propelled, free-flight models are used to obtain data on the effect of high Mach number flight on the airplane response to gusts. Because autopilots and yaw dampers add artificial damping to the airplane motions, the effect of these devices on wing and tail loads in rough air has been investigated experimentally and analytically, and for one airplane showed that increased damping of the lateral mode was effective in reducing the gust loads on the vertical tail by about 50 percent. These and other available gust data and studies have been applied to both airplane and missile operations to developing gust-load design criteria.

For several years landing impact loads have been studied intensively; consequently, methods have been developed for calculating these loads for a given landing gear with a good degree of accuracy if the initial conditions at touchdown are known. Vertical velocity at contact is the most important single parameter connected with impact loads, and an accurate statistical determination of this quantity for routine operations will make it possible to specify more precisely the value of this important design quantity. A method for obtaining statistical data on airplane vertical velocity at ground contact from measurements of center-of-gravity acceleration has been utilized to interpret acceleration peaks from VGH recorders obtained during routine operational landings. Measurements of vertical velocity for over 600 separate landings representing 6 different airlines' operations were also obtained at mile-high Denver and sea-level San Francisco airports. This new information, together with that previously available, provides a statistical sample of sufficient size for reliable analysis.

Other primary problems associated with landing aircraft result from the high speed of landings, characteristics of tires, and the friction coefficient between the tire and runway. Landing requirements for future high-speed aircraft have increased the desirability of using skid-type landing gear; consequently, a model with skid landing gear and nose wheel was investigated on a treadmill-type runway and it was found that changes which reduced the side loads on the wheel or moving the skid aft reduced the tendency toward a divergent notion. A comprehensive summary of research on the elastic and mechanical properties of tires has been prepared. For each tire characteristic semi-empirical equations which account for the major factors pertinent to the characteristic were developed. A significant contribution to the complete understanding of friction coefficient and drag loads for which a landing gear must be designed was obtained from realistic, closely controlled impact tests of a modern heavily loaded aircraft tire conducted on the Landing Loads Track for many conditions, such as vertical velocities up to 9.3 fps, forward speeds up to 110 knots, tire pressure ranging from 35 to 210 psi, wet and dry concrete surface, and wheels partially and completely locked.

The landing-impact phenomena is now well understood, although the complete determination of landing conditions remains to be made; in fact, may never be completed because of changing designs and operational procedures. Not so well understood, however, is the subject of airplane structural response to taxiing and ground handling. It has been known that taxiing and ground handling over runways and taxiways, which are more or less rough, impose loads which are critical for structural design, notably in the attachment of wing-mounted, large-mass items. As a step toward solving the taxiing and ground-handling problems, a comprehensive collection of airport profiles for the United States, Canada, and European NATO countries has been assembled through a cooperative program initiated by the Advisory Group for Aeronautical Research and Development of the North Atlantic Treaty Organization. High-speed analog or digital computers that permit simulation of all the nonlinear landing-gear and tire characteristics are being used to investigate the response of the landing gear, its associated structure, and supported load to accelerations and motions induced by taxiing over representative runway profiles.

Experimental studies of fundamentals of hydrodynamic impact loads have been completed at the Langley Impact Basin. These studies have considered the relation of airplane design and construction parameters and of airplane operating parameters to impact loads. Among the design and construction parameters studied are hull or hydro-ski configuration, airplane weight, and structural elasticity and mass distribution of the airplane. The operational-parameter studies include landing approach conditions such as trim angle, flight-path angle, velocity and aerodynamic lift, and seaway conditions. The hull and hydro-ski configurations studied were limited to basic shapes which could be incorporated in specific designs.

VIBRATION AND FLUTTER

Flutter

Flutter is a self-induced vibration of an aircraft or missile produced by the interaction of the air forces and structural stiffness and inertia. The flag or leaf fluttering in the breeze, the venetian blind vibrating in an open window, are more common examples of flutter. Flutter of an aircraft differs from these examples in that it is relatively more violent and destructive; consequently, aircraft are designed to be free from flutter, not to withstand it.

A major part of flutter research involves the determination of the speed at which flutter occurs and the mode of vibration of wind-tunnel models. One aspect of this research is the establishment of the effects of various parameters by tests of models which represent a systematic variation of particular parameters. Another aspect is to furnish experimental verification of the accuracy of theoretical prediction methods. A third aspect, and one which has become increasingly important, is the determination of the flutter characteristics of models which simulate dynamically a particular aircraft design. This affords a more accurate answer than a theoretical analysis. This is particularly true for aircraft whose structure and weight distribution are such as to produce complicated vibrational patterns and for the transonic speed range in which separated flow aerodynamics may prevail.

One of the more troublesome types of flutter has been that involving control surfaces. Control-surface flutter, including flutter of all-movable tail surfaces as well as flap-type controls, has been studied. The kernel-function method is being used to predict theoretical flutter boundaries for a series of all-movable horizontal stabilizers and these theoretical results are being compared with the experimental flutter boundaries. The widespread use of hydraulic boost servos to operate controls has introduced another factor which has an important effect on the dynamics of the control system. Experimental wind-tunnel flutter studies have been carried out, using models with miniature hydraulic components which simulate full-scale actuators.

Emphasis is being shifted to aeroelastic problems of very high speed aircraft and missiles. Considerable experimental effort has been directed toward aeroelastic studies of components of the X–15 and other hypersonic configurations. Programs to study fuel sloshing, panel flutter, aeroelastic characteristics of ICBM configurations, structural feedback instabilities, boost-glide aeroelastic characteristics, and other dynamic and static aeroelastic problems induced by hypersonic flight capabilities are receiving a larger proportion of research effort.

It has been established that aerodynamic heating increases the tendency of structures to flutter by reducing the effective stiffness. In a continuing study of this problem, a series of multiweb-wing structural models have been designed for tests in the 9- by 6-foot Thermal Structures Tunnel, where flutter data can be obtained under aerodynamic heating conditions.

Aerodynamic Aspects of Flutter

Improvements in theoretical approaches have been aimed at providing oscillatory aerodynamic forces and moments with greater accuracy. As noted in the 1957 annual report, considerable effort has gone into development of methods of flutter analysis using the kernel-function method to obtain the aerodynamic forces. Considerable success has been encountered in developing procedures for programing the kernel-function method for high-speed computing machines.

As noted previously, flutter of flap-type control surfaces has been an increasingly important problem. Particular emphasis has been placed on the measurement at transonic speeds of aerodynamic control surface derivatives pertinent to flutter. This study has included a variation of control surface contours. Similar measurement of the oscillatory derivations have been made on all movable controls and on T-tail configurations.

Panel Flutter

Panel flutter is a term used to describe a type of vibration of individual panels on sections of skin that can occur at supersonic speeds. Susceptibility of panels to this type of flutter is greater for thinner skins, larger panels, and for panels having buckles. Thus on hypersonic vehicles or thin-skinned rockets in which buckling of the skin has occurred because of loadings or heating, panel flutter is a serious problem.

Previous theoretical work has produced methods of analyses for flat, rectangular, buckled and unbuckled panels, and for infinitely long, thin cylinders. This work is being extended to include nonlinear flutter analysis of buckled rectangular panels for both large-deflection and small-deflection flutter. Another extension is concerned with the flutter of thin-walled cylinders of finite length.

Panel-flutter tests were conducted in a supersonic jet to determine if heat shields proposed for a hypersonic aircraft would be flutter free. Other experimental programs were initiated to obtain data in the 9- by 6-foot Thermal Structures Tunnel on the flutter of thin-wall cylinders typical of ICBM boosters and of blunt conical shells such as would be used for a manned satellite capsule.

STRUCTURAL MATERIALS

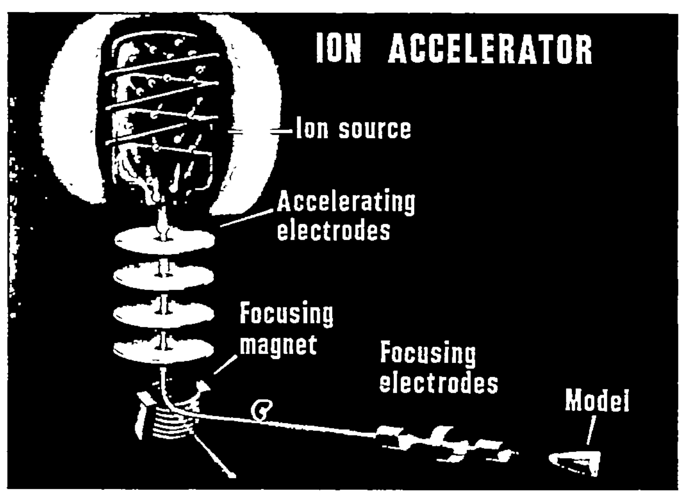
Research on structural materials has continued to be concerned primarily with materials for high-speed aircraft and missiles, although considerable work was also done on problems of fundamental importance to all materials. Consideration was also given to the materials problems created by the environment of space, such as impact on spacecraft of cosmic particles, ranging from ions to micrometeors. It is to be expected that surface pitting by ions striking spacecraft and satellites may constitute operational problems in these environments.

Not enough is known about the properties of our constructional materials at high temperatures to permit the designers to arrive at the most rational and efficient design of high-speed aircraft. The accumulation of data on the mechanical properties of materials at temperatures up to 1,800° F. has continued, and apparatus is being developed to extend the temperature range to 5,000° F. In the past year, tensile and compression creep data were obtained for 2024–T3 and 7075–T6 aluminum alloys, and generalized master curves for predicting rupture, minimum creep rate, and creep strain were derived. Studies of the effects of rapid heating on tensile properties were continued, with special consideration being given to materials of interest for structures of high-speed aircraft. Studies of the dynamic and static modulus of materials have been extended to include the determination of frequency dependence and temperature dependence of the shear and elastic moduli.

As has always been the case in the past, fatigue is still one of the major causes of failure in aircraft. Investigation of fatigue phenomena in materials included: A fundamental study of the role of dislocation and vacancies on fatigue; experimental investigation of effects of cumulative damage, based on gust-frequency spectrum; and the determination of crack propagation rates in sheet material of conventional alloys. The first series of tests to determine the effect of atmospheric corrosion on fatigue of aluminum alloys was completed, and showed that fatigue life of specimens tested out of doors can be lower by a factor of 3, as compared with fatigue life as determined by indoor tests.

Entry into the earth's atmosphere by ballistic missiles or satellites impress conditions of extreme severity. Research work on the most promising method of protecting reentry bodies that will experience the highest heat flux was continued and accelerated. Ablation tests of various promising materials were carried out at heating rates up to 2,000 Btu/ft ^{2}/sec and at stagnation temperatures to 10,000° F. A program for investigating the behavior of other materials for use at lower heating rates was continued, and a large number of conventional metals, as well as refractory metals and ceramics and cermets, were tested in the high-temperature Ceramic Heated Jet. Determination of the emissivity of structural materials, at temperatures up to 2,000° F., was continued, and apparatus is being constructed that will allow emissivity measurements up to 6,000° F.

One of the unknown factors in the operation of space vehicles is the effect of strikes by micrometeoric and larger particles. An investigation is under way of the



Magnets focus beam of ions.

effects of various projectiles striking targets which simulate full-scale structures. Spheres of various materials were fired into targets of various materials at speeds up to 10,000 ft/sec. A theoretical correlation between properties of the projectile and target materials and the results of impact was established.

The apparatus shown is being used to explore the erosion that occurs when ionized particles strike metal surfaces at speeds of 15,000 m.p.h. or faster.

OPERATING PROBLEMS

The daily operations of aircraft and missiles present problems which require solution or alleviation for purposes of safety, efficiency, and economy. Research information is also needed by the designers and manufacturers as well as the operators. For many years, therefore, the NACA has studied various aspects of aircraft operating problems such as atmospheric turbulence, icing, ditching, aircraft and missile noise, crash fire and survival, flight instrumentation, landing and takeoff operations, and aircraft braking.

The NACA has been aided in its research activities in the above areas by the deliberations of the Committee on Operating Problems, the Subcommittee on Meteorological Problems, the Subcommittee on Aircraft Noise, the Subcommittee on Flight Safety, and, until this year, the Subcommittee on Icing Problems. During this year NACA icing research has been limited to writing reports on previous investigations and to supervising the use of NACA icing research facilities by non-NACA personnel who were testing aircraft components under simulated icing conditions.

FLIGHT SAFETY

Flight safety research encompasses many problem areas associated with the operation of aircraft. Hazardous conditions may arise at any time from sources such as the runway, the weather, the engines, the instruments, the controls, and the landing gear. NACA investigations are thus aimed at specific problems to obtain information useful to the manufacturer and the aircraft crew in the industrywide effort to improve safety.

Aircraft Instrumentation

The angle between the relative wind in the plane of symmetry and the longitudinal axis of the airplane is the angle of attack, and its measurement is an important requirement for stall warning, cruise control, and armament considerations. Three types of angle-of-attack sensing devices have been tested in a wind tunnel and in flight to determine calibration and position error data. One result showed that the best sensor location for operation throughout the subsonic, transonic, and supersonic speed ranges is a position ahead of the fuselage nose.

Accurate measurement of airspeed is necessary for safe and efficient flight operations. An investigation has been made to determine the external interference effects of flow through the orifices of an airspeed head such as would occur due to instrument volume at high rates of ascent or descent in flight. The results indicated that the static-pressure error increased almost linearly with increase in mass flow through the orifices.

A study has also been made on the accuracy with which pressure altitude can be measured with current systems. The analysis showed that the accuracy depends on errors in the measuring systems, errors arising from operation of the system, and variation in atmospheric pressure. In another study a survey was made of the errors associated with the measurement of static pressure on aircraft. The errors considered were associated with the static-pressure tube or fuselage vent and the location of the sensor in the flow field of the airplane.

Engine Reliability

Turbojet engines must either be repaired or replaced after specified number of hours of operation. For reasons of safety and economy, it is necessary to know as accurately as possible when engine changes are to be accomplished. An investigation has been made to obtain information on the effect of overtemperature and heat treatment on the life of turbine buckets. Results indicated that overtemperatured buckets did not fracture in abnormally short operating times. Cracking was the principal mode of failure of buckets.

In another study a method was developed to help decide whether jet-engine compressor blades that have been nicked in service are safe from fatigue failure with continued engine operation. These nicks are the result of foreign objects being drawn into the air inlet. A procedure has been worked out for making limit charts that indicate whether a blade showing damage should be accepted or rejected.

Aircraft Ditching

For years the NACA has conducted scale-model ditching investigations of aircraft configurations to furnish designers and operators with information on ditching characteristics and behavior. Models of fighters, bombers, and various types of transports have been tested by utilizing a catapult and water tank system. With the advent of turbojet aircraft, the need for additional ditching data on new configurations has been met by recent tests. In addition, ditching aids such as hydro-skis and hydrofoils attached to the aircraft fuselage bottom have been under study to determine their effectiveness in helping to make a water landing more successful.

In recent studies, an investigation of a 0.043-scale dynamic model of a jet transport was undertaken to study its ditching behavior in rough water. Test results have indicated that hydro-skis or hydrofoils may be made to improve the ditching performance and reduce the damage to the fuselage bottom. Twin hydro-skis with a loading of about 2,500 lbs/square foot resulted in smooth runs with very little damage to the fuselage bottom. Smaller hydro-skis with a loading of 4,400 psf, or twin hydrofoils with a loading of 7,500 psf, or a single hydrofoil with a loading of about 8,300 psf, all resulted in ditching runs which caused moderate damage to the aft fuselage of the model.

In tests with the landing gear extended, the results indicated that the nose gear will fail and that the main gear may or may not fail. When the main gear failed, a deep run resulted causing moderate damage throughout the length of the fuselage bottom. When the main gear did not fail, a dive resulted and the front portion of the fuselage bottom was demolished, causing severe flooding of the entire fuselage.

Flight Operations

Several investigations have been continued in an effort to determine more accurately pilot and aircraft characteristics in different flight areas. Under certain conditions, a pilot's capability to control his airplane may be compromised. The effects of airplane acceleration on the pilot's arm as a result of maneuvers or power changes have been studied with a small side-located controller to allow arm support and hand motions. Several pilots participated in ground tests to obtain measurements of their force capabilities with such a device. (See photo.)

Pilot's seat with control stick.

Further tests have been made to determine the suitability of a takeoff indicator to detect abnormal airplane acceleration during takeoff such as occasioned by loss of engine power. The instrument performed satisfactorily in a jet bomber and other tests are being continued in a large, jet-transport-type airplane.

A general flight study of jet transport aircraft has been conducted to obtain operational information in the approach, landing, and cruise regions. Using an airplane similar to the commercial jet transport, preliminary data were obtained on sinking speed prior to touchdown, lift and drag characteristics, high-speed characteristics, lateral control combinations, and yaw damping augmentation.

As a first step in a general investigation of the use in flight of thrust reversers on turbojet-powered airplanes, the effect of a target-type thrust reverser on the aerodynamic characteristics of a full-scale jet airplane has been measured in a wind tunnel. Changes in the aerodynamic characteristics of the airplane, particularly with regard to the pitching moment, were determined for various amounts of thrust reversal.

In another study, a fully modulating target-type thrust reverser has been installed and tested on a jet-fighter airplane to evaluate the effect of more powerful incremental thrust control devices on the landing-approach characteristics of aircraft. The thrust reverser was also studied to determine its usefulness for inflight deceleration from high speeds and as a braking device to reduce the ground-roll distance in landings.

Runway and Landing-Gear Research

There are several problems associated with airport runways which can lead to hazardous aircraft operating conditions. For example, tire behavior during landing on wet runways has been found to contribute to a number of aircraft accidents. As part of a general program, the NACA has investigated the effects of water depth, tire speed, pressure and tread, braking friction forces, and cornering forces by use of an instrumented tire treadmill. The results indicate that the maximum and the full-skid braking friction coefficients decrease rapidly with increasing velocity until all braking effectiveness is lost and a tire-planing condition is reached.

Runway lights which project above the runway surface are a potential hazard to aircraft operations. Accordingly, an investigation was made to obtain data on the landing-gear loads developed during landing and taxiing tests over various types of runway lights. The test results indicated that vertical loads on the nose landing gear were larger for landings on the lights than on plain concrete, and that the nose gear loads developed while taxiing over the lights were relatively more severe than those developed on the main gear.

A study was also made of ground-reaction forces measured during landing impacts of a large airplane. Results of the analysis of the data showed the effect of vertical velocity at contact on the vertical force and the variations of coefficients of friction with slip ratio during spinup on wet and dry concrete surfaces.

Crash Survival Research

Several fighter airplanes were crashed under circumstances approximating those observed in the military service; unflared landings at various angles, a ground cartwheel, and a ground loop. The magnitude, duration, and direction of the crash accelerations were measured on the airplane structure and on an anthropomorphic dummy installed in the cockpit. The accelerations measured were compared with existing data on human tolerance to the sudden loads that occur in crashes to see whether the human tolerances had been exceeded.

AERONAUTICAL METEOROLOGY

To achieve the goal of safe and efficient all-weather flight, aircraft and missile designers and operators must take into account the changes in weather conditions and the effects of the meteorological elements on the vehicle. Two of the environmental problems, atmospheric turbulence and icing, have been under study by the NACA for several years, while other factors have only been under investigation from time to time.

Atmospheric Turbulence

Rough air flight of aircraft brings discomfort to passengers and crew, may cause structural damage, may decrease the fatigue life of the airframe, and can present control problems to the pilot. In addition, turbulent air poses problems for missile takeoff and reentry operations. As one approach to the gust-loads problem, the NACA has been active for years in obtaining information on the extent, frequency, and severity of atmospheric turbulence in clouds and free air at altitudes up to 60,000 feet. Data have been obtained by specially instrumented aircraft, parachute assemblies, and rockets over several areas of the world.

The severest turbulence is generally found in the clouds associated with storm areas, but the available gust data are not sufficient for study. Accordingly, a fighter-type airplane has been specially instrumented for probing cumulus-type clouds to obtain gust measurements useful to designers, operators, and meteorologists.

The characteristics of turbulent air below 1,000 feet are not too well known; however, such information is required for landing and takeoff operations as well as low-level military missions. A study of gust data derived primarily from wind-tower measurements indicates that turbulence intensity is affected by windspeed, altitude, temperature lapse rate, and the ground roughness.

At the higher altitudes, investigations of cloud and clear-air turbulence have continued in order to shed more light on these phenomena. The NACA has cooperated with the Navy, Air Force, and Weather Bureau by furnishing VGH (velocity, acceleration, altitude) recorders and by analyzing gust data for several programs. Instrumented aircraft have probed the jetstream and have flown in and near hurricanes to obtain the needed data.

As part of the NACA analytical investigation of the aircraft-gust problem, a method has been developed to calculate the statistical forces and moments exerted on an airplane due to random distributions of gusts. A previous report covered the development of the rolling and yawing moments on a wing in random turbulence. Recent calculations have been made of the complete lateral response of an airplane while flying in continuous isotropic turbulence.

Environmental Data

Besides turbulence, other meteorological elements in and beyond our atmosphere affect the design and operation of aircraft and missiles. From time to time in answer to requests for specific information, the NACA has been able to obtain and analyze data useful to manufacturers, operators, and meteorologists.

Knowledge of atmospheric temperatures is of importance to designers and operators of aircraft and missiles. To provide this information, a study has been made of radiosonde temperature measurements taken over a 5-year period for several locations in the Northern Hemisphere. Probability distributions of temperature up to 100,000 feet have been determined from data provided, sorted, and tabulated by the U.S. Weather Bureau.

In cooperation with the Air Weather Service, an NACA flight program with instrumented U–2 aircraft is continuing to collect data up to 55,000 feet on such variables as water vapor, wind shear, clouds, temperature, the jetstream, clear-air turbulence, ozone, and cosmic rays. Recent data on atmospheric turbulence over the western part of the United States have been published.

The Icing Cloud

For efficient design of icing protection systems for aircraft and missiles, detailed and statistical knowledge is required of worldwide icing conditions in which these vehicles may operate. The NACA has sought to obtain information on the extent, frequency, and severity of icing conditions by installation of suitable instruments in research, commercial, and military aircraft. Currently, icing-rate meters are on loan to several aircraft companies and Government organizations.

The icing problem for high-altitude, intercepter aircraft has been evaluated and the results published. At two Air Defense Command airbases, fighter-interceptors equipped with NACA icing-rate meters collected data during climb and descent operations, and information was obtained on the frequency and severity of icing clouds over the north-central and northwestern United States.

AIRCRAFT ICING

Because of the state of the art, active NACA icing research on aircraft and engine components has been diminishing since 1956 and was terminated in the fiscal year 1957. NACA icing research activities conducted during the fiscal year 1958 have been concerned primarily with completing the analyses and publication of the results of icing programs conducted over the preceding 24 months.

The Lewis Flight Propulsion Laboratory icing tunnel, because of its unique features, is continually made available to the aircraft industry and Government organizations under a plan whereby industry representatives conduct icing tests on their specific models with guidance by NACA personnel. The raw data obtained from such development studies are available upon request to interested personnel. Analysis and reporting of the data are being made by each company or organization. Thus, NACA reports on these projects are usually not prepared for formal publication.

Water-Droplet Impingement and Icing Protection

In order to design efficient icing protection systems for an aircraft engine component or airframe surface, detailed information is required as to the area and weight of ice accumulation under various icing and operating conditions. To determine droplet impingement characteristics, the NACA has tested both models and full-scale components in the Lewis Laboratory icing research tunnel. In addition, analytical studies have been made to obtain similar data.

An experimental investigation has been conducted to measure the amount and areas of cloud-droplet impingement on a ¼-scale model of a fighter airplane engine inlet. Angles of attack from 2° to 8°, droplet diameters from 7 to 23 microns, and ratios of inlet to free-stream velocity from 0.4 to 1.5 were studied. Significant impingement rates and areas were found on the curved outboard wall of the inlet duct and on regions within a few inches of the cowl lips and leading edges of the duct splitter vanes.

Icing tests were conducted in the 6- by 9-foot icing research tunnel to evaluate the effectiveness of ice protection systems for a jet transport. The proposed systems utilized hot gas to anti-ice the leading edge regions of the wing and cyclic-electric deicing for the tail surfaces. The manufacturer's personnel conducted the tests and the raw data are available for study.

As part of a general study of icing and icing protection for bodies of revolution, an investigation was conducted to determine the impingement characteristics, heat transfer, and icing-protection requirements for simple bodies of revolution. The bodies investigated included spheres, elliptical forebodies, and a conical forebody of 30° included angle. The investigation covered a wide range of conditions both in clear air and in icing, and included studies at angles of attack both with and without rotation.

The rate and the area of cloud-droplet impingement has been obtained for the above types of bodies. Results are presented in the form of dimensionless parameters, which enable the icing characteristics of bodies of revolution to be determined over a wide range of flight and atmospheric conditions.

Data on the heat transfer in clear air from the elliptical body of fineness ratio 3.0 and the conical forebody have also been obtained. Information required in the use of conventional wet-air analysis for the design of anti-icing systems for bodies of revolution was determined from these data.

Penalties Due to Icing

Aerodynamic effects caused by ice formations on an unheated NACA 65A004 airfoil were determined over a wide range of icing conditions and the results published. The drag changes due to these ice formations were correlated with the various icing conditions, as well as with the physical dimensions of the ice accumulated and with the measured droplet-impingement rates. The correlation resulted in an empirical equation that may be used to predict changes in drag coefficients for this airfoil based on meteorological, impingement, and flight conditions. The correlation was also extended to include aerodynamic data for four other airfoils.

Noise Research

The noise produced by current jet engines is of sufficient intensity to cause damage to nearby personnel and aircraft structures and serious discomfort or annoyance to personnel over a considerable distance from the engine. Noise annoyance alone is a major problem in the introduction of jet transports and may be an important factor influencing the operation of such transports.

The NACA has been conducting at its Lewis and Langley Research Centers a broad research program to determine the mechanisms by which jet noise is produced and to find means for reducing jet noise. Conclusive evidence from this research program shows that the major source of noise from a turbojet or rocket engine is the exhaust and that the noise from this source dominates all other noise during full power operations. The jet exhaust noise is caused by the intense turbulence produced by the mixing of the high speed exhaust stream with the surrounding air as well as by oscillating shock waves within the jet exhaust and interaction of these shock waves and turbulence. The major NACA research effort has been directed toward reduction of noise created by turbulence since this is the dominant factor in the production of noise during take-off and climb of jet aircraft which are the operating conditions producing the noise nuisance in communities near airports. Reducing the velocity of the jet exhaust will reduce the noise; however, this imposes a penalty on the efficiency of the engine. Since most of the jet noise is produced within ten nozzle diameters downstream of a conventional circular nozzle, it has been determined that less noise would be produced if the jet exhaust stream could be slowed down as rapidly as possible after leaving the nozzle; that is in less distance than the ten diameters. This has been accomplished by the development of special jet exit nozzles which rapidly mix low energy surrounding air into the jet exhaust stream and thereby decrease the overall jet velocity and noise. Scores of nozzle configurations have been investigated to determine the basic design parameters required to produce the best nozzles for given conditions. The corrugated multiple-tube and shrouded nozzles now being produced for jet transports are examples of nozzles developed from this program. Some nozzles are designed to produce significant reductions in overall noise output, others are designed to alter the mixing process in such a way as to change the amount of noise in certain frequencies, and still others are designed to reduce the width of the pattern of noise distribution beneath an aircraft so as to minimize the number of people annoyed by take-offs. More research is underway to increase the noise suppression effectiveness of these nozzles.

Although suppressors do reduce the noise level, they also add weight to the aircraft, slightly decrease engine performance, and increase the drag of the airplane. The amount of noise suppression desired must be balanced against the economic and performance penalties imposed by the use of these suppressors. As a result of extensive NACA wind tunnel tests of suppressor configurations, the aerodynamic performance of suppressors has been evaluated to help assess a reasonable balance. Much additional work is required before a satisfactory solution can be attained.

With the advent of supersonic aircraft a new problem has entered into flight operations—the sonic boom. This boom is the shock wave produced by an object traveling through the air at supersonic speeds and is similar to the bow wave from a boat. This boom or wave can easily be of sufficient intensity to crack plaster and break windows in buildings beneath the path of the supersonic aircraft. The NACA has investigated the parameters which affect the strength of this wave when it hits the ground and has found that primary factors are the altitude of the aircraft, the climatic conditions, and the size of the aircraft. The speed of the aircraft is not important after the aircraft is well into the supersonic regime. Data are being obtained which will allow the estimation of the strength of sonic booms for various flight conditions, and more work is being done to establish flight procedures to minimize the boom intensity. Some research has been accomplished on aircraft design concepts for the future which may reduce the magnitude of the boom problem, and more work is underway along such lines.

The effects of sonic boom from one aircraft on other nearby aircraft also have been investigated, and it appears that if the aircraft are not flying at the same speed so that one aircraft remains in the shock wave from the other aircraft, or if the aircraft are separated by distances of approximately 500 feet or more, the sonic boom problem appears to be of negligible importance to aircraft in flight.

RESEARCH PUBLICATIONS

REPORTS

1296. A Theoretical Study of the Aerodynamics of Slender Cruciform-Wing Arrangements and Their Wakes. By John R. Spreiter and Alvin H. Sacks.
1297. Nonlifting Wing-Body Combinations with Certain Geometric Restraints Having Minimum Wave Drag at Low Supersonic Speeds. By Harvard Lomax.
1298. An Analysis of the Effects of Aeroelasticity on Static Longitudinal Stability and Control of a Swept-Wing Airplane. By Richard B. Skoog.
1299. Correlation, Evaluation, and Extension of Linearized Theories for Tire Motion and Wheel Shimmy. By Robert F. Smiley.
1300. Basic Considerations in the Combustion of Hydrocarbon Fuels With Air. By Propulsion Chemistry Division, Lewis Flight Propulsion Laboratory.
1301. Linearized Lifting-Surface and Lifting-Line Evaluations of Sidewash Behind Rolling Triangular Wings at Supersonic Speeds. By Percy J. Bobbitt.
1302. On Panel Flutter and Divergence of Infinitely Long Unstiffened and Ring-Stiffened Thin-Walled Circular Cylinders. By Robert W. Leonard and John M. Hedgepeth.
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Part II—COMMITTEE ORGANIZATION AND MEMBERSHIP

The National Advisory Committee for Aeronautics was established by act of Congress approved March 3, 1915 (U.S. Code, title 50, sec. 151). The organic act as amended provided that the Committee be composed of 17 members appointed by the President, including two representatives each of the Department of the Air Force, the Department of the Navy, and the Civil Aeronautics Authority; one representative each of the Smithsonian Institution, the U.S. Weather Bureau, and the National Bureau of Standards; and "one Department of Defense representative who is acquainted with the needs of aeronautical research and development." The law further provided that the membership include seven members appointed for five-year terms from persons "acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences." The representatives of the Government organizations were appointed without definite terms, and all members served as such without compensation.

In accordance with the regulations of the Committee as approved by the President, the chairman and vice chairman and the chairman and vice chairman of the Executive Committee were elected annually. The officers now serving, reelected at the annual meeting of the Committee October 10, 1957, are: Dr. James H. Doolittle, Chairman of the NACA and Chairman of the Executive Committee; Dr. Leonard Carmichael, Vice Chairman of the NACA; and Dr. Detlev W. Bronk, Vice Chairman of the Executive Committee.

The following changes in membership have taken place during the past year:

On October 22, 1957, President Eisenhower appointed Hon. Paul D. Foote, Assistant Secretary of Defense (Research and Engineering), as the Department of Defense representative on the Committee authorized in the law. He succeeded Hon. Clifford C. Furnas, whose membership on NACA was terminated February 15, 1957, as a result of his resignation as Assistant Secretary of Defense (Research and Development).

The NACA membership of Lt. Gen. Donald L. Putt, who had been serving as Deputy Chief of Staff, Development, of the Air Force, was automatically terminated June 30, 1958, on his retirement from the Air Force. He had been a member of NACA more than nine years, having been appointed March 22, 1949. Because of the legislation then pending in the Congress which would result in the termination of the existence of the NACA, the President did not appoint a successor to General Putt on the Committee. In the interim, Lt. Gen. Roscoe C. Wilson, USAF, General Putt's successor as Deputy Chief of Staff, Development, served as acting member of NACA.

Because of his detachment as Deputy Chief of Naval Operations (Air) and transfer to duty with the Atlantic Fleet, the membership of Vice Adm. William V. Davis, USN, on the NACA was terminated May 22, 1958. As in the case of General Putt, the President did not appoint a successor on the Committee, and in the meantime Vice Adm. Robert B. Pirie, USN, Admiral Davis' successor in his Navy post, served as acting NACA member.

Reference was made in the opening statement of this report to the National Aeronautics and Space Act of 1958 (Public Law 85–568), approved July 29, 1958. In accordance with that act, and by proclamation of the Administrator of the National Aeronautics and Space Administration which he has indicated he will publish in the Federal Register of September 30, 1958, the National Advisory Committee for Aeronautics will cease to exist at the close of business September 30, 1958. At that time all its functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records will be transferred to the National Aeronautics and Space Administration. All memberships on the NACA will then be terminated.

The members of the National Advisory Committee for Aeronautics at the end of its existence, September 30, 1958, are as follows:

James H. Doolittle, Sc. D., Vice President, Shell Oil Co., Chairman.
Leonard Carmichael, Ph. D., Secretary, Smithsonian Institution, Vice Chairman.
Allen V. Astin, Ph. D., Director, National Bureau of Standards.
Preston R. Bassett, D. Sc.
Detlev W. Bronk, Ph. D., President, Rockefeller Institute for Medical Research.
Frederick C. Crawford, Sc. D., Chairman of the Board, Thompson Products, Inc.
Paul D. Foote, Ph. D., Assistant Secretary of Defense (Research and Engineering).
Wellington T. Hines, Rear Admiral, U.S. Navy, Deputy and Assistant Chief of the Bureau of Aeronautics.
Jerome C. Hunsaker, Sc. D., Massachusetts Institute of Technology.
Charles J. McCarthy, S.B., Chairman of the Board, Chance Vought Aircraft, Inc.
James T. Pyle, A.B., Administrator of Civil Aeronautics.
Francis W. Reichelderfer, Sc. D., Chief, U.S. Weather Bureau.
Edward V. Rickenbacker, Sc. D., Chairman of the Board, Eastern Air Lines, Inc.

Louis S. Rothschild, Ph. B., Under Secretary of Commerce for Transportation.

Thomas D. White, General, U.S. Air Force, Chief of Staff.

In its coordination of aeronautical research and the formulation of its research programs, the NACA has been assisted for a number of years by four main technical committees. Under each of these committees, subcommittees have been organized varying in number from three to eight, the total number in 1958 being 23. On February 26, 1958, the names of the four main technical committees, as well as those of certain subcommittees, were changed to indicate more definitely their cognizance of problems applicable to missiles and spacecraft as well as aircraft. The four main technical committees now are: Committee on Aircraft, Missile, and Spacecraft Aerodynamics (formerly Committee on Aerodynamics); Committee on Aircraft, Missile, and Spacecraft Propulsion (formerly Committee on Power Plants for Aircraft); Committee on Aircraft, Missile, and Spacecraft Construction (formerly Committee on Aircraft Construction); and Committee on Aircraft Operating Problems (formerly Committee on Operating Problems). Effective January 1, 1958, the Subcommittee on Icing Problems, formerly organized under the Committee on Operating Problems, was discontinued, since it was the opinion of the NACA that the demands for research in this field had decreased to such an extent that the maintenance of a separate subcommittee was not justified, and such research as was needed in this field could be conducted under the cognizance of the Subcommittee on Flight Safety and the Subcommittee on Meteorological Problems.

The NACA at its meeting on November 21, 1957, authorized the establishment of a Special Committee on Space Technology, to be composed of experts especially qualified in the field, to survey the whole problem of space technology from the point of view of needed research and development, and to make recommendations to the NACA. It was pointed out that, while the NACA already had a substantial effort on problems of flight beyond the earth's atmosphere, as exemplified by the X–15 research airplane being constructed by North American Aviation, Inc., as a joint Air Force-Navy-NACA project, and by its research program on ballistic missile problems, there was need for a review of the whole problem of space technology. The Special Committee on Space Technology was organized in January 1958 under the chairmanship of Dr. H. Guyford Stever, Associate Dean of Engineering of the Massachusetts Institute of Technology, and has been engaged in a survey of the entire field, with the aid of seven working groups established for study of the following areas: Space Research Objectives; Vehicular Program; Reentry; Range, Launch, and Tracking Facilities; Instrumentation; Space Surveillance; and Human Factors and Training. The report of the Special Committee on Space Technology will be completed in the near future.

The NACA has also been assisted since 1945 by an Industry Consulting Committee, whose function has been to advise the NACA as to general research policy and programs, especially with regard to the needs of industry.

At the final meeting of the National Advisory Committee for Aeronautics on August 21, 1958, the members of the Committee expressed the firm opinion that the advice and cooperation of NACA committees and subcommittees have been a highly significant factor in the effective discharge of the duties of NACA.

The Administrator of the National Aeronautics and Space Administration, Hon. T. Keith Glennan, has indicated that the proclamation which he will issue for publication in the Federal Register of September 30 will include a provision that the committees and subcommittees of the NACA are being reconstituted advisory committees to the NASA for the purpose of bringing their current work to orderly completion.

The membership of the committees and their subcommittees and working groups is as follows:

COMMITTEE ON AIRCRAFT, MISSILE, AND SPACECRAFT AERODYNAMICS

Mr. Preston R. Bassett, Chairman.

Dr. Theodore P. Wright, Vice President for Research, Cornell University, Vice Chairman.

Maj. Gen. Ralph P. Swofford, Jr., USAF, Assistant Deputy Chief of Staff, Development, U.S. Air Force.

Col. Randall D. Keator, USAF, Chief, Aircraft Laboratory, Wright Air Development Center.

Rear Adm. L. D. Coates, USN, Assistant Chief of the Bureau of Aeronautics for Research and Development, Department of the Navy.

Mr. Abraham Hyatt, Bureau of Aeronautics, Department of the Navy.

Capt. Robert L. Townsend, USN, Assistant Director, Research and Development Division, Bureau of Ordnance, Department of the Navy.

Maj. Gen. H. N. Toftoy, USA, Commanding General, Aberdeen Proving Ground.

Col. George P. Seneff, Jr., USA, Office of the Chief of Research and Development, Department of the Army.

Mr. Harold D. Hoekstra, Civil Aeronautics Administration.

Dr. Hugh L. Dryden (ex officio).

Mr. Floyd L. Thompson, NACA Langley Aeronautical Laboratory.

Mr. Russell G. Robinson, NACA Ames Aeronautical Laboratory.

Dr. Milton U. Clauser, Director, Aeronautical Research Laboratory, The Ramo-Wooldridge Corp.

Capt. W. S. Diehl, USN (Ret.).

Mr. Clarence L. Johnson, Vice President, Research and Development, Lockheed Aircraft Corp.

Dr. A. Kartveli, Vice President, Research and Development, Republic Aviation Corp.

Mr. Schuyler Kleinhans, Assistant Chief Engineer, Santa Monica Division, Douglas Aircraft Co., Inc.

Dr. Clark B. Millikan, Director, Daniel Guggenheim Aeronautical Laboratory, California Institute of Technology.

Mr. Kendall Perkins, Vice President, Engineering, McDonnell Aircraft Corp.
Mr. George S. Schairer, Director of Research, Seattle Division, Boeing Airplane Co.
Prof. William R. Sears, Cornell University.
Mr. R. C. Sebold, Vice President, Engineering, Convair, Division of General Dynamics Corp.
Mr. H. A. Storms, Jr., Chief Engineer, Los Angeles Division, North American Aviation, Inc.
Mr. George S. Trimble Jr., Vice President-Chief Engineer, The Martin Co.
Mr. Milton B. Ames, Jr., Secretary

Subcommittee on Fluid Mechanics

Prof. William R. Sears, Cornell University, Chairman.
Lt. Col. B. W. Marschner, USAF, Air Force Missile Development Center.
Mr. E. Haynes, Air Force Office of Scientific Research.
Dr. Frederick S. Sherman, Office of Naval Research, Department of the Navy.
Mr. John D. Nicolaides, Bureau of Ordnance, Department of the Navy.
Dr. Joseph Sternberg, Ballistic Research Laboratories, Aberdeen Proving Ground.
Dr. G. B. Schubauer, Chief, Fluid Mechanics Section, National Bureau of Standards.
Dr. Adolf Busemann, NACA Langley Aeronautical Laboratory.
Mr. Clinton E. Brown, NACA Langley Aeronautical Laboratory.
Dr. D. R. Chapman, NACA Ames Aeronautical Laboratory.
Mr. Robert T. Jones, NACA Ames Aeronautical Laboratory.
Dr. John C. Evvard, NACA Lewis Flight Propulsion Laboratory.
Dr. J. V. Charyk, Aeronutronic Systems, Inc.
Prof. Wallace D. Hayes, Princeton University.
Prof. Otto Laporte, University of Michigan.
Prof. Lester Lees, California Institute of Technology.
Prof. Hans W. Liepmann, California Institute of Technology.
Prof. C. C. Lin, Massachusetts Institute of Technology.
Prof. E. L. Resler, Jr., Cornell University.
Mr. Ernest O. Pearson, Jr., Secretary

Subcommittee on High-Speed Aerodynamics

Dr. Clark B. Millikan, Director, Daniel Guggenheim Aeronautical Laboratory, California Institute of Technology, Chairman.
Mr. Robert F. Robinson, Air Research and Development Command.
Mr. Oscar Seidman, Bureau of Aeronautics, Department of the Navy.
Dr. H. H. Kurzweg, Associate Technical Director for Aeroballistic Research, Naval Ordnance Laboratory.
Mr. C. L. Poor, Chief, Exterior Ballistics Laboratory, Ballistic Research Laboratories, Aberdeen Proving Ground.
Mr. John Stack, NACA Langley Aeronautical Laboratory.
Mr. H. Julian Allen, NACA Ames Aeronautical Laboratory.
Dr. Abe Silverstein, NACA Lewis Flight Propulsion Laboratory.
Mr. Walter C. Williams, NACA High-Speed Flight Station.
Mr. John R. Clark, Assistant Chief Engineer, Chance Vought Aircraft, Inc.
Mr. Alexander H. Flax, Vice President and Assistant Director, Technical, Cornell Aeronautical Laboratory, Inc.
Mr. L. P. Greene, Chief Aerodynamicist, North American Aviation, Inc.
Mr. R. P. Jackson, General Manager, Tactical Weapon Systems Division, Aeronutronic Systems, Inc.
Mr. C. J. Koch, Chief of Staff, Advanced Design, The Martin Co.
Mr. John G. Lee, Director of Research, United Aircraft Corp.
Dr. Albert E. Lombard, Jr., Director of Research, McDonnell Aircraft Corp.
Mr. Harlowe J. Longfelder, Systems Engineering Director, Boeing Airplane Co.
Prof. John R. Markham, Professor of Aeronautical Engineering, Massachusetts Institute of Technology.
Mr. W. F. Radcliffe, Chief of Aerophysics, Convair, Division of General Dynamics Corp.
Mr. Ronald Smelt, Director, New Design Office, Missile Systems Division, Lockheed Aircraft Corp.
Mr. Albert J. Evans, Secretary

Subcommittee on Aerodynamic Stability and Control

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Mr. Jerome Teplitz, Bureau of Aeronautics, Department of the Navy.
Mr. Joseph E. Long, Bureau of Ordnance, Department of the Navy.
Mr. J. G. McHugh, Transportation Research and Engineering Command.
Mr. D. L. Baker, Civil Aeronautics Administration.
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Mr. Charles F. Hall, NACA Ames Aeronautical Laboratory.
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Mr. Maxwell W. Hunter, Chief Missiles Design Engineer, Douglas Aircraft Co., Inc.
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Prof. E. E. Larrabee, Massachusetts Institute of Technology.
Mr. Conrad A. Lau, Chance Vought Aircraft, Inc.
Mr. Jack D. Brewer, Secretary

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Mr. George L. Yingling, Wright Air Development Center.
Dr. Gerhard W. Braun, Air Force Missile Development Center.
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Mr. J. M. Lee, Bureau of Ordnance, Department of the Navy.
Mr. Karl L. Kocmanek, Signal Corps Engineering Laboratories.
Mr. Charles W. Mathews, NACA Langley Aeronautical Laboratory.
Mr. Harry J. Goett, NACA Ames Aeronautical Laboratory.
Mr. A. S. Boksenbom, NACA Lewis Flight Propulsion Laboratory.
Mr. Joseph Weil, NACA High-Speed Flight Station.
Mr. Frank Andrix, Director of Engineering, Avionics Division, Bell Aircraft Corp.
Mr. Frank A. Gaynor, Aeronautical and Ordnance Systems Division, General Electric Co.
Dr. William J. Jacobi, The Ramo-Wooldridge Corp.

Mr. Floyd E. Nixon, Manager, Systems Analysis Department, The Martin Co.

Mr. Louis A. Payne, Convair, Division of General Dynamics Corp.

Mr. Duncan Pitman, Missiles Division, Douglas Aircraft Co., Inc.

Dr. Allen E. Puckett, Associate Director, Systems Development Laboratories, Hughes Aircraft Co.

Mr. O. H. Schuck, Minneapolis-Honeywell Regulator Co.

Dr. Robert C. Seamans, Jr., RCA Airborne Systems Laboratory.

Mr. Bernard Maggin, Secretary

Subcommittee on Internal Flow

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Mr. Frederick T. Rall, Jr., Wright Air Development Center.

Mr. Robert E. Roy, Wright Air Development Center.

Mr. R. T. Miller, Bureau of Aeronautics, Department of the Navy.

Dr. Thomas W. Williams, Office of Naval Research, Department of the Navy.

Mr. V. S. Kupelian, U.S. Naval Ordnance Experimental Unit.

Mr. John V. Becker, NACA Langley Aeronautical Laboratory.

Mr. Richard Scherrer, NACA Ames Aeronautical Laboratory.

Mr. DeMarquis D. Wyatt, NACA Lewis Flight Propulsion Laboratory.

Mr. Donald R. Bellman, NACA High-Speed Flight Station.

Mr. J. S. Alford, Aircraft Gas Turbine Division, General Electric Co.

Mr. Bernard F. Beckelman, Boeing Airplane Co.

Mr. John A. Drake, Director of Long-Range Planning and Research Programs, Marquardt Aircraft Co.

Mr. Harry Drell, Propulsion Department Manager, Lockheed Aircraft Corp.

Dr. Antonio Ferri, Head, Department of Aeronautical Engineering, Polytechnic Institute of Brooklyn.

Mr. Donald J. Jordan, Pratt & Whitney Aircraft, United Aircraft Corp.

Mr. Darrel B. Parke, McDonnell Aircraft Corp.

Mr. M. A. Sulkin, Chief Thermodynamicist, North American Aviation, Inc.

Mr. Stafford W. Wilbur, Secretary

Subcommittee on Low-Speed Aerodynamics

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Maj. E. B. Owens, USAF, Air Research and Development Command.

Mr. Harvey L. Anderson, Wright Air Development Center.

Mr. Gerald L. Desmond, Bureau of Aeronautics, Department of the Navy.

Maj. Darrell L. Ritter, USMC, Office of Naval Research, Department of the Navy.

Lt. Col. T. E. Haynes, USA, Office of the Chief of Research and Development, Department of the Army.

Mr. John Beebe, Office of the Chief of Transportation, Department of the Army.

Mr. C. W. Von Rosenberg, Chief, Flight Test Branch, Civil Aeronautics Administration.

Mr. Charles H. Zimmerman, NACA Langley Aeronautical Laboratory.

Mr. Charles W. Harper, NACA Ames Aeronautical Laboratory.

Mr. Jack Fischel, NACA High-Speed Flight Station.

Mr. M. M. Blair, North American Aviation, Inc., Columbus, Ohio.

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Mr. D. H. Jacobson, Aeroproducts Operations, Allison Division, General Motors Corp.

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Mr. James A. O'Malley, Jr., Chief, Aerodynamic and Propulsion Design Department, Bell Aircraft Corp.

Dean Kenneth Razak, Dean, School of Engineering, University of Wichita.

Mr. W. Z. Stepniewski, Chief, Research and Development, Vertol Aircraft Corp.

Mr. Ralph W. May, Secretary

Subcommittee on Seaplanes

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Mr. Eugene H. Handler, Bureau of Aeronautics, Department of the Navy.

Mr. F. W. S. Locke, Jr., Bureau of Aeronautics, Department of the Navy.

Mr. Phillip Eisenberg, Office of Naval Research, Department of the Navy.

Mr. M. St. Denis, David W. Taylor Model Basin.

Comdr. T. E. Maurer, USN, Naval Air Test Center, Patuxent.

Capt. R. R. Johnson, USCG, Western Area, U.S. Coast Guard.

Mr. William J. Husic, Civil Aeronautics Administration.

Mr. John B. Parkinson, NACA Langley Aeronautical Laboratory.

Mr. H. E. Brooke, Chief of Hydrodynamics, Convair, Division of General Dynamics Corp.

Mr. C. L. Fenn, Chief Engineer, Edo Corp.

Mr. Grover Loening.

Mr. J. D. Pierson, The Martin Co.

Mr. Daniel Savitsky, Stevens Institute of Technology.

Mr. Henry B. Suydam, Grumman Aircraft Engineering Corp.

Mr. Ralph W. May, Secretary

Subcommittee on Helicopters

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Mr. Paul A. Simmons, Jr., Wright Air Development Center.

Comdr. J. D. Kuser, USN, Bureau of Aeronautics, Department of the Navy.

Mr. T. L. Wilson, Office of Naval Research, Department of the Navy.

Lt. Col. Harry L. Bush, USA, Office of the Chief of Research and Development, Department of the Army.

Mr. L. J. Borges, Office of the Chief of Transportation, Department of the Army.

Capt. W. W. Vennel, USCG, Headquarters, U.S. Coast Guard.

Mr. Herbert M. Toomey, Civil Aeronautics Administration.

Mr. Richard C. Dingeldein, NACA Langley Aeronautical Labortary.

Mr. F. B. Gustafson, NACA Langley Aeronautical Laboratory.

Mr. Donald H. Wood, NACA Ames Aeronautical Laboratory.

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Dr. W. H. Pickering, Director, Jet Propulsion Laboratory, California Institute of Technology.
Dr. Louis N. Ridenour, Assistant General Manager, Research and Development, Missile Systems Division, Lockheed Aircraft Corp.
Dr. J. A. Van Allen, State University of Iowa.

Mr. Carl B. Palmer, Secretary

Working Group on Space Research Objectives

Dr. J. A. Van Allen, State University of Iowa, Chairman.
Prof. Dale R. Corson, Cornell University, Vice Chairman.
Col. Norman C. Appold, USAF, Air Research and Development Command.
Mr. Robert Cornog, The Ramo-Wooldridge Corp.
Mr. Robert P. Haviland, Systems Planning Engineer, General Electric Co.
Dr. J. R. Pierce, Director of Research, Electrical Communications, Murray Hill Laboratory, Bell Telephone Laboratories, Inc.
Prof. Lyman Spitzer, Jr., Princeton University Observatory.

Mr. E. O. Pearson, Secretary

Working Group on Vehicular Program

Dr. Wernher von Braun, Director, Development Operations Division, Army Ballistic Missile Agency, Chairman.
Mr. S. K. Hoffman, General Manager, Rocketdyne Division, North American Aviation, Inc., Vice Chairman.
Col. Norman C. Appold, USAF, Air Research and Development Command.
Mr. Abraham Hyatt, Bureau of Aeronautics, Department of the Navy.
Dr. Louis N. Ridenour, Assistant General Manager, Research and Development, Missile Systems Division, Lockheed Aircraft Corp.
Dr. Abe Silverstein, NACA Lewis Flight Propulsion Laboratory.
Dr. Krafft A. Ehricke, Convair, Astronautics, Division of General Dynamics Corp.
Mr. M. W. Hunter, Chief Missiles Design Engineer, Douglas Aircraft Co., Inc.
Mr. C. C. Ross, Vice President, Engineering, Aerojet-General Corp.
Dr. Homer J. Stewart, Jet Propulsion Laboratory, California Institute of Technology.
Mr. George S. Trimble, Jr., Vice President, Engineering, The Martin Co.

Mr. William H. Woodward, Secretary

Working Group on Reentry

Dr. Milton U. Clauser, Director, Aeronautical Research Laboratory, The Ramo-Wooldridge Corp., Chairman.
Mr. H. Julian Allen, NACA Ames Aeronautical Laboratory, Vice Chairman.
Dr. Mac C. Adams, Deputy Director, Avco Research Laboratory, Avco Manufacturing Corp.
Dr. Alfred J. Eggers, Jr., NACA Ames Aeronautical Laboratory.
Mr. Maxime A. Faget, NACA Langley Aeronautical Laboratory.
Dr. A. H. Flax, Vice President and Assistant Director, Technical, Cornell Aeronautical Laboratory, Inc.
Prof. Lester Lees, Guggenheim Aeronautical Laboratory, California Institute of Technology.
Mr. Harlowe J. Longfelder, Systems Engineering Director, Boeing Airplane Co.
Dr. J. C. McDonald, Missile Systems Division, Lockheed Aircraft Corp.
Prof. S. A. Schaaf, University of California.
Col. John P. Stapp, USAF, Chief, Aero Medical Laboratory, Wright Air Development Center.

Mr. R. Fabian Goranson, Secretary

Working Group on Range, Launch, and Tracking Facilities

Mr. J. R. Dempsey, Manager, Convair, Astronautics, Division of General Dynamics Corp., Chairman.
Mr. Robert R. Gilruth, NACA Langley Aeronautical Laboratory, Vice Chairman.
Col. Paul T. Cooper, USAF, Deputy Commander, Range, Air Force Missile Test Center.
Mr. L. G. deBey, Chief, Electronic Measurements Branch, Ballistic Research Laboratories, Aberdeen Proving Ground.
Mr. Carl Ernest Duckett, Army Ballistic Missile Agency.
Comdr. Robert F. Freitag, USN, Naval Air Missile Test Center.
Prof. J. Allen Hynek, Astrophysical Observatory, Smithsonian Institution.
Mr. John T. Mengel, Naval Research Laboratory.
Mr. Grayson Merrill, General Manager, Fairchild Guided Missiles Division, Fairchild Engine & Airplane Corp.

Mr. Carl B. Palmer, Secretary

Working Group on Instrumentation

Dr. W. H. Pickering, Director, Jet Propulsion Laboratory, California Institute of Technology, Chairman.
Dr. Louis N. Ridenour, Assistant General Manager, Research and Development, Missile Systems Division, Lockheed Aircraft Corp., Vice Chairman.
Dr. Henrik W. Bode, Vice President, Bell Telephone Laboratories, Inc.

Mr. Robert W. Buchheim, The Rand Corp.
Mr. Harry J. Goett, NACA Ames Aeronautical Laboratory.
Dr. Albert C. Hall, Director of Engineering, Denver Division, The Martin Co.
Mr. Eberhardt Rechtin, Jet Propulsion Laboratory, California Institute of Technology.
Dr. William T. Russell, Space Technology Laboratories, Inc.
Dr. Robert C. Seamans, Jr., RCA Airborne Systems Laboratory.
Mr. Bernard Maggin, Secretary

Working Group on Space Surveillance

Dr. Hendrik W. Bode, Vice President, Bell Telephone Laboratories, Inc., Chairman.
Dr. W. H. Pickering, Director, Jet Propulsion Laboratory, California Institute of Technology, Vice Chairman.
Mr. Wilbur B. Davenport, Jr., Head, Communications and Components Division, Lincoln Laboratory, Massachusetts Institute of Technology.
Mr. W. B. Hebenstreit, Director, Special Programs, Space Technology Laboratories, Inc.
Mr. Richard S. Leghorn, ITEK Corp.
Mr. K. G. Macleish, Assistant Director, Research and Development Department, Apparatus and Optical Division, Eastman Kodak Co.
Dr. William B. McLean, Technical Director, U.S. Naval Ordnance Test Station.
Mr. A. H. Shapley, Boulder Laboratories, National Bureau of Standards.
Dr. Fred L. Whipple, Director, Astrophysical Observatory, Smithsonian Institution.
Mr. Carl B. Palmer, Secretary

Working Group on Human Factors and Training

Dr. W. Randolph Lovelace II, Lovelace Foundation for Medical Education and Research, Chairman.
Mr. A. Scott Crossfield, North American Aviation, Inc.
Mr. Hubert M. Drake, NACA High-Speed Flight Station.
Brig. Gen. Donald D. Flickinger, USAF (MC), Director of Human Factors and Staff Surgeon, Air Research and Development Command.
Col. Edward B. Giller, USAF, Deputy Commander for Special Projects, Air Force Special Weapons Center.
Dr. James D. Hardy, Medical Laboratory, U.S. Naval Air Development Center.
Mr. Wright Haskell Langham, Los Alamos Scientific Laboratory, University of California.
Dr. Ulrich C. Luft, Head, Physiology Department, Lovelace Foundation for Medical Education and Research.
Mr. Boyd C. Myers II, Secretary

Part III—FINANCIAL REPORT

Funds appropriated for the Committee for the fiscal years 1958 and 1959 and obligations against the fiscal year 1958 appropriations are as follows:

	Fiscal year 1958		Fiscal year 1959
	Allotments	Obligations	Allotments
SALARIES AND EXPENSES APPROPRIATION			
NACA Headquarters	$1, 971, 000	$1, 958, 201	$2, 083, 650
Langley Aeronautical Laboratory	28, 947, 150	28, 897, 306	30, 368, 000
Ames Aeronautical Laboratory	15, 194, 498	15, 149, 417	16, 380, 350
Lewis Flight Propulsion Laboratory	25, 221, 525	25, 192, 055	27, 538, 000
High-Speed Flight Station	2, 584, 527	2, 565, 353	2, 833, 100
Pilotless Aircraft Station	1, 750, 310	1, 743, 025	1, 179, 920
Western Coordination Office	40, 797	39, 170	49, 605
Wright-Patterson Liaison Office	19, 000	18, 782	21, 375
Research contracts with educational institutions	410, 000	410, 000	850, 000
Research contracts with Government agencies	90, 000	90, 000	150, 000
Cost of Federal Employees Salary Increase Act of 1958 included above	(1, 508, 807)	(1, 488, 719)	(3, 354, 000)
Unobligated balance	−152, 598	12, 900	--------------
Total	[1] 76, 076, 209	76, 076, 209	[2] 81, 454, 000
CONSTRUCTION AND EQUIPMENT APPROPRIATION			
Langley Aeronautical Laboratory	11, 879, 000	3, 877, 606	11, 350, 000
Ames Aeronautical Laboratory	11, 355, 000	5, 162, 672	3, 720, 000
Lewis Flight Propulsion Laboratory	16, 406, 000	5, 269, 793	7, 800, 000
Pilotless Aircraft Station	1, 560, 000	580, 440	130, 000
Unobligated balance	--------------	[4] 26, 309, 489	--------------
Total	[3] 41, 200, 000	41, 200, 000	[5] 23, 000, 000

[1] Appropriated in the Independent Offices Appropriation Act, 1958, approved June 29, 1957; the Second Supplemental Appropriation Act, 1958, approved Mar. 28, 1958; and Public Law 85-472, approved June 30, 1958.

[2] $78,100,000 appropriated in the Independent Offices Appropriation Act, 1959, approved Aug. 28, 1958; includes $3,454,000 to be submitted in a supplemental appropriation request to cover the fiscal year 1959 cost of the Federal Employees Salary Increase Act, 1958.

[3] Appropriated in the Independent Offices Appropriation Act, 1958, approved June 29, 1957; and the Second Supplemental Appropriation Act, 1958, approved Mar. 28, 1958.

[4] This balance remains available until expended.

[5] Appropriated in the Independent Offices Appropriation Act, 1959, approved Aug. 28, 1958.

Funds appropriated in the Supplemental Appropriation Act, 1959, approved August 27, 1958, for the National Aeronautics and Space Administration for the fiscal year 1959 are set forth below. Under authority of the National Aeronautics and Space Act of 1958, approved July 29, 1958, all balances of National Advisory Committee for Aeronautics funds were transferred to National Aeronautics and Space Administration accounts at the close of business September 30, 1958.

	Fiscal year 1959
Salaries and Expenses appropriation	$5, 000, 000
Research and Development appropriation	[1] 167, 000, 000
Construction and Equipment appropriation	25, 000, 000

[1] Includes funds in the amount of $117 million transferred from the Department of Defense.

Part IV—FINAL MEETING OF NACA

The final meeting of the National Advisory Committee for Aeronautics was held at 2 p.m., August 21, 1958, at its headquarters, 1512 H Street NW., Washington, D.C. Present at this meeting were:

James H. Doolittle, Sc. D., Vice President, Shell Oil Co., Chairman.
Leonard Carmichael, Ph. D., Secretary, Smithsonian Institution, Vice Chairman.
Allen V. Astin, Ph. D., Director, National Bureau of Standards.
Preston R. Bassett, Sc. D., retired.
Frederick C. Crawford, Sc. D., Chairman of the Board, Thompson Products Co., Inc.
Paul D. Foote, Ph. D., Assistant Secretary of Defense, Research and Engineering.
Wellington T. Hines, Rear Admiral, USN, Assistant Chief for Procurement, Bureau of Aeronautics, Navy.
Charles J. McCarthy, B.S., Chairman of the Board, Chance Vought Aircraft, Inc.
James T. Pyle, A.B., Administrator of Civil Aeronautics.
Francis W. Reichelderfer, Sc. D., Chief, U.S. Weather Bureau.
Louis S. Rothschild, Ph. B., Undersecretary of Commerce for Transportation.
Thomas D. White, General, U.S. Air Force, Chief of Staff.

And on invitation:

Vice Adm. Robert B. Pirie, USN, acting member.
Maj. Gen. Marvin C. Demler, USAF, representing Lt. Gen. Roscoe C. Wilson, acting member.

And:

Hugh L. Dryden, Director.
John F. Victory, Executive Secretary.
John W. Crowley, Jr., Associate Director for Research.

Also present on invitation of Chairman Doolittle was Dr. T. Keith Glennan, newly appointed Administrator of the National Aeronautics and Space Administration (NASA). The Chairman announced that Dr. Glennan and Dr. Hugh Dryden, Director of NACA, had been confirmed by the Senate and had taken their respective oaths of office as Administrator and Deputy Administrator of NASA at the White House in the presence of President Eisenhower on August 19.

The Chairman welcomed Dr. Glennan and expressed the best wishes of the NACA for complete success in his new duties.

Dr. Glennan said he recognized in some degree the kind of task he was undertaking, and that he thought it quite wonderful to have the NACA staff and organization as a base on which to build. He then exhibited and explained a draft chart of proposed organization based on plans developed by the NACA Headquarters staff, with some modifications. Especially important, he said, would be an Office of Program Planning and Evaluation, reporting to the Administrator and the Deputy Administrator, and cooperating with the National Aeronautics and Space Council in the development of national programs of aeronautical and space activities. Dr. Glennan said he would welcome the advice of members of NACA at any time.

Chairman Doolittle extended to Dr. Glennan the thanks, congratulations, and best wishes of the members of NACA. Dr. Glennan expressed his appreciation of the privilege of appearing before the Committee, and, with the applause of the members, withdrew.

National Aeronautics and Space Act of 1958

The Chairman reported that the National Aeronautics and Space Act of 1958 (Public Law 85–568), approved by the President July 29, 1958, established the National Aeronautics and Space Administration, headed by an Administrator appointed from civilian life by the President by and with the advice and consent of the Senate, with a Deputy Administrator appointed in the same manner.

The functions of the Administration provided by the act are—

1. To plan, direct, and conduct aeronautical and space activities, except activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States, which will be the responsibility of the Department of Defense.
2. To arrange for participation by the scientific community in planning scientific measurements and observations to be made through use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations.
3. To provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.

In Section 301 of the act, it is provided:

The National Advisory Committee for Aeronautics, on the effective date of this section, shall cease to exist. On such date all functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records of that organization, shall be transferred to the Administration.

This section shall take effect 90 days after the date of the enactment of this act, or on any earlier date on which the Administrator shall determine, and announce by proclamation

Final meeting of National Advisory Committee for Aeronautics, August 21, 1958. Around table clockwise: Hon. James T. Pyle, Administrator of Civil Aeronautics Dr. Hugh L. Dryden, Director, NACA; Mr. Preston R. Bassett; Hon. Louis S. Rothschild, Under Secretary of Commerce for Transportation; Dr. Leonard Carmichael, Secretary, Smithsonian Institution; Dr. James H. Doolittle, Chairman, NACA; Dr. John F. Victory, Executive Secretary, NACA; Dr. Francis W. Reichelderfer, Chief, U.S. Weather Bureau; Dr. Frederick C. Crawford, Chairman of the Board, Thompson Products, Inc.; Maj. Gen. Marvin C. Demler, USAF (attended in place of Lt. Gen. Roscoe C. Wilson, USAF, Deputy Chief of Staff, Development); General Thomas D. White, USAF, Chief of Staff, U.S. Air Force; Hon. Paul D. Foote, Assistant Secretary of Defense (Research and Engineering); Vice Admiral Robert B. Pirie, USN, Deputy Chief of Naval Operations (Air); Rear Admiral Wellington T. Hines, USN, Deputy and Assistant Chief, Bureau of Aeronautics; Mr. Charles J. McCarthy, Chairman of the Board, Chance Vought Aircraft, Inc.; and J. W. Crowley, Associate Director for Research, NACA.

published in the Federal Register, that the Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by this act.

(In accordance with the proclamation issued in accordance with the foregoing authority, the National Aeronautics and Space Administration became the legal successor to the National Advisory Committee for Aeronautics, effective as at the close of business September 30, 1958.)

Further provisions of the act include—

A declaration that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

The establishment of a nine-member National Aeronautics and Space Council, to include the President, the Secretary of State, the Secretary of Defense, the Administrator of NASA, the Chairman of the Atomic Energy Commission, one additional member to be appointed by the President from Federal Agencies, and three other members to be appointed by the President from among individuals in private life who are eminent in science, engineering, technology, education, administration, or public affairs; the functions of the Council being to advise the President regarding policies, plans, programs, and accomplishments of United States agencies engaged in aeronautical and space activities, and the development of a comprehensive program.

NOTE.—The President on September 4 appointed as members of the Council: James H. Doolittle, Detlev W. Bronk, W. A. M. Burden, and Alan T. Waterman.

Provision for a Civilian-Military Liaison Committee, headed by a chairman to be appointed by the President, and including representatives of the Department of Defense and the Departments of the Army, Navy, and Air Force, and of the NASA.

STATEMENT BY THE PRESIDENT, JULY 29, 1958

I have today signed H.R. 12575, the National Aeronautics and Space Act of 1958.

The enactment of this legislation is a historic step, further equipping the United States for leadership in the space age. I wish to commend the Congress for the promptness with which it has created the organization and provided the authority needed for an effective national effort in the fields of aeronautics and space exploration.

The new act contains one provision that requires comment. Section 205 authorizes cooperation with other nations and groups of nations in work done pursuant to the act and in the peaceful application of the results of such work, pursuant to international agreements entered into by the President with the advice and consent of the Senate. I regard this section merely as recognizing that international treaties may be made in this field, and as not precluding, in appropriate cases, less formal arrangements for cooperation. To construe the section otherwise would raise substantial constitutional questions.

The present National Advisory Committee for Aeronautics (NACA), with its large and competent staff and well-equipped laboratories, will provide the nucleus for the NASA. The NACA has an established record of research performance and of cooperation with the armed services. The combination of space exploration responsibilities with the NACA's traditional aeronautical research functions is a natural evolution.

The enactment of the law establishing the NACA in 1915 proved a decisive step in the advancement of our civil and military aviation. The Aeronautics and Space Act of 1958 should have an even greater impact on our future.

After the Committee disposed of all business before it, including approval of its final statement to the Congress of the United States, submitting its 44th annual report, the following statements were made:

Undersecretary of Commerce Rothschild said that his 4 years of service as a member of the NACA had been a wonderful and illuminating experience and that it had been a great pleasure to serve with men of the caliber of NACA.

Gen. Thomas D. White, Chief of Staff, USAF, said that he would write a letter to the Chairman thanking the NACA for its support, cooperation, and assistance, virtually since the beginning of military aviation.

Vice Adm. Robert B. Pirie, DCNO (Air), expressed the same sentiments regarding the services rendered by the NACA to the Navy throughout the past 43 years.

Dr. Leonard Carmichael, Secretary, Smithsonian Institution, said that he was proud of the fact that the Smithsonian Institution, through its former Secretary, Dr. Charles D. Walcott, had been instrumental in the establishment of NACA and that all Secretaries of the Smithsonian since that time have served as members of NACA.

NOTE.—Dr. Walcott was the father of NACA, the first Chairman of its Executive Committee, 1915–19, and from 1919 until his death in 1927, chairman of the main committee.

Dr. Doolittle said it had been a great pleasure for him to serve with the other members for the past 10 years and thanked them for their cooperation and assistance during his chairmanship.

Dr. Victory said that the nameplate now on the back of each member's chair would be removed, suitably mounted, and transmitted to each member as a souvenir of his service with NACA.

At the conclusion of the brief meeting of the Committee held at the Ames Aeronautical Laboratory, Moffett Field, Calif., in connection with the triennial inspection of that Laboratory, July 14, 1958, the Executive Secretary, Dr. Victory, made a statement on behalf of the NACA staff, expressing appreciation of the leadership of the members of NACA throughout its history. He was instructed to record that statement. It follows:

This may be the last meeting of the National Advisory Committee for Aeronautics which was established by law in 1915 to supervise and direct the scientific study of the problems of flight with a view to their practical solution. The great record of outstanding contributions to the progress of aeronautics made by the Committee, the members can always remember with pride and satisfaction.

On behalf of the entire staff of the organization, numbering about 7,800, I wish to express to the members of the Committee our profound sense of gratitude for the privilege and the honor that has been ours in working under the inspiring leadership of the members of the Committee and their illustrious chairmen throughout the life of the Committee. From their fine example and patriotic devotion to the cause of American supremacy in the air, from their vision and success in providing novel research facilities and ideal working conditions, we have drawn the inspiration and determination to do our best for the utmost advancement of aeronautical science in America.

We share the pride that is justly yours in the accomplishments of the era that is closing, and whatever the future may hold, it will ever be our high resolve to continue to render to our country loyal and devoted service."

Following are the letters to the Chairman, NACA, which General White, Admiral Pirie, and Secretary Rothschild offered to prepare on behalf of the Air Force, Navy, and Department of Commerce.

DEPARTMENT OF THE AIR FORCE
OFFICE OF THE CHIEF OF STAFF
UNITED STATES AIR FORCE
WASHINGTON, D. C.

26 August 1958

Dr. James H. Doolittle
Chairman
National Advisory Committee
for Aeronautics
1512 H Street, Northwest
Washington 25, D. C.

Dear Dr. Doolittle:

It was with mixed feelings that I attended the last meeting of the National Advisory Committee for Aeronautics on 21 August 1958.

There was regret at the passing of an agency that for 43 years has set the world's standard in aeronautical research. The United States as a nation, and the Air Force in particular, are deeply indebted to the NACA. In war and peace NACA has led the way; and there has always been, for us in the Air Force, the knowledge that NACA was ready to help in any aerodynamic trouble.

I hope that the new National Aeronautics and Space Agency, which will encompass many of the people of the old NACA, will go forward with the same competence and spirit of cooperation to reach new levels of accomplishment in the enlarged field.

Let me, on behalf of the Air Force, express sincerest thanks for all that the NACA has done for us over the years, and ask that you transmit my thanks to all the people of NACA who have served so long and so well.

Sincerely,

THOMAS D. WHITE
Chief of Staff

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
1512 H STREET NORTHWEST
WASHINGTON 25, D. C.

TELEPHONE: LIBERTY 5-6700
TWX: WA 755

LANGLEY AERONAUTICAL LABORATORY
LANGLEY FIELD, VA.

AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIF.

LEWIS FLIGHT PROPULSION LABORATORY
21000 BROOKPARK ROAD, CLEVELAND 11, OHIO

September 10, 1958

General Thomas D. White, USAF
Chief of Staff
Department of the Air Force
Washington 25, D.C.

Dear General White:

Your letter of August 26 is deeply appreciated by me personally. I am taking the liberty of bringing it to the attention of the nearly 8,000 employes of the National Advisory Committee for Aeronautics.

The great skill with which these devoted people have performed their researches over the years has been the prime reason for the contributions made by the NACA as a partner, together with the Military Services and the industry, on the air power team.

I know I can assure you, on behalf of these dedicated workers, that they will continue to merit the confidence, and the support, of the American people as they take up new and tremendously important work as the nucleus of the National Aeronautics and Space Administration.

Sincerely,

J. H. Doolittle
Chairman

THE ASSISTANT SECRETARY OF THE NAVY FOR AIR
WASHINGTON

17 SEP 1958

Dear Jimmy:

Upon the occasion of the disestablishment of the National Advisory Committee for Aeronautics, I would like to express the sincere appreciation of the United States Navy for the many achievements made by the NACA in the advancement of American aviation. Through the years, from the birth of the National Advisory Committee for Aeronautics by Congressional Act in 1915, when aircraft speeds of 100 knots were the marvel of the day, research by the NACA has been responsible for world leadership in aviation by the United States. During World War II, when American aviation manufacturing reached fantastic proportions, the superiority of design of American aircraft was in no small measure a compliment to the vision of the laboratories of the NACA in probing the unknown.

The well known fighters of the Navy, the Corsair, the Wildcat, and the Hellcat, which maintained control of the air in the Pacific and did so much to make the eventual naval victories possible, were all products of the application of research done by the NACA. Development in NACA laboratories of high lift devices, low drag wings, high speed propellers, improved engine cooling systems, and improved aircraft structural systems allowed the Navy's carrier task forces to strike the enemy where and when we chose.

Korea found the Navy operating jet aircraft from carriers in combat for the first time, and the distinct success of these operations was in no small measure proof of the validity of basic research conducted by the NACA.

Today, as speeds of manned aircraft near the hypersonic range, and with missile velocities transiting the hypersonic areas, the Free World owes a debt of gratitude to the comprehensive fundamental research in the problems of flight conducted by the NACA. The wealth of knowledge acquired by the NACA in its thirty-three years is a broad foundation upon which the Nation can build as the Jet Age gives way to the Age of Space.

Again, Jimmy, I would like to express the sincere appreciation of the Navy for the outstanding contributions to naval aviation made by the National Advisory Committee for Aeronautics. The National Aeronautics and Space Administration has a rich heritage indeed, and we of the Navy rejoice in the good news of your appointment as a member of the Board.

Sincerely,

Garry

GARRISON NORTON

James H. Doolittle, Sc.D.,
Chairman
National Advisory Committee for Aeronautics
1512 H Street NW
Washington 25, D.C.

THE SECRETARY OF COMMERCE
WASHINGTON 25

September 15 1958

Dear General Doolittle:

On behalf of the Department of Commerce and its representatives who serve as members of the National Advisory Committee for Aeronautics, it is a pleasure to express appreciation for the outstanding achievements of the NACA during its 43 years of activity. American leadership in aeronautics is due in no small measure to the research carried forward in NACA laboratories and to developments fostered by the Committee over the years in co-operation with industry and government agencies concerned with aviation. Many studies and discoveries that have led to revolutionary advancements in aeronautics have come directly from the laboratories of the organization. Forthcoming expansion of operations to explore outer space and develop the possibilities of interplanetary vehicles will bring an important transition which the United States will accomplish by building on experience and knowledge to which the NACA has contributed very materially.

From the beginning of the NACA in 1915, the Department of Commerce has always had one or more representatives in the membership of the Committee. The Director of the National Bureau of Standards was ex officio one of the original members. After passage of the Air Commerce Act of 1926 the Assistant Secretary of Commerce for Air also was a member, succeeded later on the Committee by the Administrator of Civil Aeronautics. In 1940 when the Weather Bureau was transferred to the Department of Commerce, the Chief of that Bureau, whose office had been among the original ex officio members, became another from this Department to serve on the Committee. In recent years the Under Secretary of Commerce for Transportation, Mr. Louis S. Rothschild, has made a fourth member from the Department of Commerce.

I express the feelings of these representatives as well as my own when I say that it has been a real privilege to have had an active part in the work of the Committee. It is indeed gratifying to see how successfully this unique group has functioned as an advisory and executive body. Although the organization and its advisory group will change with inauguration of the National

- 2 -

Aeronautics and Space Agency, the interest of the Department of Commerce in future progress in these highly important fields will continue undiminished, and I look forward to continued cooperation and participation by the Department and its representatives in the advancement of aeronautics and space exploration.

Sincerely,

Sinclair Weeks

Secretary of Commerce

General James H. Doolittle
Chairman, National Advisory
Committee for Aeronautics
1512 H Street, N.W.
Washington 25, D.C.

APPENDIX

Public Law 85-568
85th Congress, H.R. 12575
July 29, 1958

AN ACT To provide for research into problems of flight within and outside the earth's atmosphere, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—SHORT TITLE, DECLARATION OF POLICY AND DEFINITIONS

National Aeronautics and Space Act of 1958

SHORT TITLE

SEC. 101. This Act may be cited as the "National Aeronautics and Space Act of 1958".

DECLARATION OF POLICY AND PURPOSE

SEC. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201(e). 72 Stat. 426.

(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives: 72 Stat. 427.

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

(d) It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), and (c).

DEFINITIONS

SEC. 103. As used in this Act—

(1) the term "aeronautical and space activities" means (A) research into, and the solution of, problems of flight within and outside the earth's atmosphere, (B) the development, construction, testing, and operation for research purposes of aeronautical and space vehicles, and (C) such other activities as may be required for the exploration of space; and

(2) the term "aeronautical and space vehicles" means aircraft, missiles, satellites, and other space vehicles, manned and unmanned, together with related equipment, devices, components, and parts.

TITLE II—COORDINATION OF AERONAUTICAL AND SPACE ACTIVITIES

NATIONAL AERONAUTICS AND SPACE COUNCIL

Establishment.

SEC. 201. (a) There is hereby established the National Aeronautics and Space Council (hereinafter called the "Council") which shall be composed of—

(1) the President (who shall preside over the meetings of the Council);

72 Stat. 427.
72 Stat. 428.

(2) the Secretary of State;

(3) the Secretary of Defense;

(4) the Administrator of the National Aeronautics and Space Administration;

(5) the Chairman of the Atomic Energy Commission;

(6) not more than one additional member appointed by the President from the departments and agencies of the Federal Government; and

(7) not more than three other members appointed by the President, solely on the basis of established records of distinguished achievement, from among individuals in private life who are eminent in science, engineering, technology, education, administration, or public affairs.

Alternate.

(b) Each member of the Council from a department or agency of the Federal Government may designate another officer of his department or agency to serve on the Council as his alternate in his unavoidable absence.

(c) Each member of the Council appointed or designated under paragraphs (6) and (7) of subsection (a), and each alternate member designated under subsection (b), shall be appointed or designated to serve as such by and with the advice and consent of the Senate, unless at the time of such appointment or designation he holds an office in the Federal Government to which he was appointed by and with the advice and consent of the Senate.

(d) It shall be the function of the Council to advise the President with respect to the performance of the duties prescribed in subsection (e) of this section.

Duties of President.

(e) In conformity with the provisions of section 102 of this Act, it shall be the duty of the President to—

(1) survey all significant aeronautical and space activities, including the policies, plans, programs, and accomplishments of all agencies of the United States engaged in such activities;

(2) develop a comprehensive program of aeronautical and space activities to be conducted by agencies of the United States;

(3) designate and fix responsibility for the direction of major aeronautical and space activities;

(4) provide for effective cooperation between the National Aeronautics and Space Administration and the Department of Defense in all such activities, and specify which of such activities may be carried on concurrently by both such agencies notwithstanding the assignment of primary responsibility therefor to one or the other of such agencies; and

(5) resolve differences arising among departments and agencies of the United States with respect to aeronautical and space activities under this Act, including differences as to whether a particular project is an aeronautical and space activity.

Employees. Compensation.

(f) The Council may employ a staff to be headed by a civilian executive secretary who shall be appointed by the President by and with the advice and consent of the Senate and shall receive compensation at the rate of

$20,000 a year. The executive secretary, subject to the direction of the Council, is authorized to appoint and fix the compensation of such personnel, including not more than three persons who may be appointed without regard to the civil service laws or the Classification Act of 1949 and compensated at the rate of not more than $19,000 a year, as may be necessary to perform such duties as may be prescribed by the Council in connection with the performance of its functions. Each appointment under this subsection shall be subject to the same security requirements as those established for personnel of the National Aeronautics and Space Administration appointed under section 203(b)(2) of this Act. 63 Stat. 954. 5 USC 1071 note. Security check.

(g) Members of the Council appointed from private life under subsection (a)(7) may be compensated at a rate not to exceed $100 per diem, and may be paid travel expenses and per diem in lieu of subsistence in accordance with the provisions of section 5 of the Administrative Expenses Act of 1946 (5 U.S.C. 73b–2) relating to persons serving without compensation. Per diem. 72 Stat. 428. 72 Stat. 429. 69 Stat. 394.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEC. 202. (a) There is hereby established the National Aeronautics and Space Administration (hereinafter called the "Administration"). The Administration shall be headed by an Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate, and shall receive compensation at the rate of $22,500 per annum. Under the supervision and direction of the President, the Administrator shall be responsible for the exercise of all powers and the discharge of all duties of the Administration, and shall have authority and control over all personnel and activities thereof. Administrator.

(b) There shall be in the Administration a Deputy Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate, shall receive compensation at the rate of $21,500 per annum, and shall perform such duties and exercise such powers as the Administrator may prescribe. The Deputy Administrator shall act for, and exercise the powers of, the Administrator during his absence or disability. Deputy Administrator.

(c) The Administrator and the Deputy Administrator shall not engage in any other business, vocation, or employment while serving as such. Restriction.

FUNCTIONS OF THE ADMINISTRATION

SEC. 203. (a) The Administration, in order to carry out the purpose of this Act, shall—

(1) plan, direct, and conduct aeronautical and space activities;

(2) arrange for participation by the scientific community in planning scientific measurements and observations to be made through use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations; and

(3) provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.

(b) In the performance of its functions the Administration is authorized—

(1) to make, promulgate, issue, rescind, and amend rules and regulations governing the manner of its operations and the exercise of the powers vested in it by law; Rules and regulations.

(2) to appoint and fix the compensation of such officers and employees as may be necessary to carry out such functions. Such officers and employees shall be appointed in accordance with the civil-service laws and their compensation fixed in accordance with the Classification Act of 1949, except that (A) to the extent the Administrator deems such action necessary to the discharge of his responsibilities, he may appoint and fix the compensation (up to a limit of $19,000 a year, or up to a limit of $21,000 a year for a maximum of ten positions) of not more than two hundred and sixty of the scientific, engineering, and administrative personnel of the Administration without regard to such laws, and (B) to the extent the Administrator deems such action necessary to recruit specially qualified scientific and engineering talent, he may establish the entrance grade for scientific and engineering personnel without previous service in the Federal Government at a level up to two grades higher than the grade provided for such personnel under the General Schedule established by the Classification Act of 1949, and fix their compensation accordingly; Employees. 63 Stat. 954. 5 USC 1071 note. 72 Stat. 429. 72 Stat. 430.

Acquisition of property.

(3) to acquire (by purchase, lease, condemnation, or otherwise), construct, improve, repair, operate, and maintain laboratories, research and testing sites and facilities, aeronautical and space vehicles, quarters and related accommodations for employees and dependents of employees of the Administration, and such other real and personal property (including patents), or any interest therein, as the Administration deems necessary within and outside the continental United States; to lease to others such real and personal property; to sell and otherwise dispose of real and personal property (including patents and rights thereunder) in accordance with the provisions of the Federal Property and Administrative Services Act of 1949, as amended (40 U.S.C. 471 et seq.); and to provide by contract or otherwise for cafeterias and other necessary facilities for the welfare of employees of the Administration at its installations and purchase and maintain equipment therefor;

63 Stat. 377.

Gifts.

(4) to accept unconditional gifts or donations of services, money, or property, real, personal, or mixed, tangible or intangible;

Contracts, etc. 60 Stat. 809.

(5) without regard to section 3648 of the Revised Statutes, as amended (31 U.S.C. 529), to enter into and perform such contracts, leases, cooperative agreements, or other transactions as may be necessary in the conduct of its work and on such terms as it may deem appropriate, with any agency or instrumentality of the United States, or with any State, Territory, or possession, or with any political subdivision thereof, or with any person, firm, association, corporation, or educational institution. To the maximum extent practicable and consistent with the accomplishment of the purpose of this Act, such contracts, leases, agreements, and other transactions shall be allocated by the Administrator in a manner which will enable small-business concerns to participate equitably and proportionately in the conduct of the work of the Administration;

Agency cooperation.

(6) to use, with their consent, the services, equipment, personnel, and facilities of Federal and other agencies with or without reimbursement, and on a similar basis to cooperate with other public and private agencies and instrumentalities in the use of services, equipment, and facilities. Each department and agency of the Federal Government shall cooperate fully with the Administration in making its services, equipment, personnel, and facilities available to the Administration, and any such department or agency is authorized notwithstanding any other provision of law, to transfer to or receive from the Administration, without reimbursement, aeronautical and space vehicles, and supplies and equipment other than administrative supplies or equipment;

Advisory committees.

(7) to appoint such advisory committees as may be appropriate for purposes of consultation and advice to the Administration in the performance of its functions;

Coordination.

(8) to establish within the Administration such offices and procedures as may be appropriate to provide for the greatest possible coordination of its activities under this Act with related scientific and other activities being carried on by other public and private agencies and organizations;

72 Stat. 430.
72 Stat. 431.
60 Stat. 810.

(9) to obtain services as authorized by section 15 of the Act of August 2, 1946 (5 U.S.C. 55a), at rates not to exceed $100 per diem for individuals;

Employment Aliens.

(10) when determined by the Administrator to be necessary, and subject to such security investigations as he may determine to be appropriate, to employ aliens without regard to statutory provisions prohibiting payment of compensation to aliens;

Retired officers.

(11) to employ retired commissioned officers of the armed forces of the United States and compensate them at the rate established for the positions occupied by them within the Administration, subject only to the limitations in pay set forth in section 212 of the Act of June 30, 1932, as amended (5 U.S.C. 59a);

68 Stat. 18. Agreements.

(12) with the approval of the President, to enter into cooperative agreements under which members of the Army, Navy, Air Force, and Marine Corps may be detailed by the appropriate Secretary for services in the performance of functions under this Act to the same extent as that to which they might be lawfully assigned in the Department of Defense; and

(13) (A) to consider, ascertain, adjust, determine, settle, and pay, on behalf of the United States, in full satisfaction thereof, any claim for $5,000 or less against the United States for bodily injury, death, or damage to or loss of real or personal property resulting from the conduct of the Administration's functions as specified in subsection (a) of this section, where such claim is presented to the Administration in writing within two years after the accident or incident out of which the claim arises; and Claims.

(B) if the Administration considers that a claim in excess of $5,000 is meritorious and would otherwise be covered by this paragraph, to report the facts and circumstances thereof to the Congress for its consideration. Report to Congress.

CIVILIAN-MILITARY LIAISON COMMITTEE

SEC. 204. (a) There shall be a Civilian-Military Liaison Committee consisting of—

(1) a Chairman, who shall be the head thereof and who shall be appointed by the President, shall serve at the pleasure of the President, and shall receive compensation (in the manner provided in subsection (d)) at the rate of $20,000 per annum;

(2) one or more representatives from the Department of Defense, and one or more representatives from each of the Departments of the Army, Navy, and Air Force, to be assigned by the Secretary of Defense to serve on the Committee without additional compensation; and

(3) representatives from the Administration, to be assigned by the Administrator to serve on the Committee without additional compensation, equal in number to the number of representatives assigned to serve on the Committee under paragraph (2).

(b) The Administration and the Department of Defense, through the Liaison Committee, shall advise and consult with each other on all matters within their respective jurisdictions relating to aeronautical and space activities and shall keep each other fully and currently informed with respect to such activities.

(c) If the Secretary of Defense concludes that any request, action, proposed action, or failure to act on the part of the Administrator is adverse to the responsibilities of the Department of Defense, or the Administrator concludes that any request, action, proposed action, or failure to act on the part of the Department of Defense is adverse to the responsibilities of the Administration, and the Administrator and the Secretary of Defense are unable to reach an agreement with respect thereto, either the Administrator or the Secretary of Defense may refer the matter to the President for his decision (which shall be final) as provided in section 201(e). 72 Stat. 431. 72 Stat. 432.

(d) Notwithstanding the provisions of any other law, any active or retired officer of the Army, Navy, or Air Force may serve as Chairman of the Liaison Committee without prejudice to his active or retired status as such officer. The compensation received by any such officer for his service as Chairman of the Liaison Committee shall be equal to the amount (if any) by which the compensation fixed by subsection (a)(1) for such Chairman exceeds his pay and allowances (including special and incentive pays) as an active officer, or his retired pay. Chairman.

INTERNATIONAL COOPERATION

SEC. 205. The Administration, under the foreign policy guidance of the President, may engage in a program of international cooperation in work done pursuant to this Act, and in the peaceful application of the results thereof, pursuant to agreements made by the President with the advice and consent of the Senate.

REPORTS TO THE CONGRESS

SEC. 206. (a) The Administration shall submit to the President for transmittal to the Congress, semiannually and at such other times as it deems desirable, a report of its activities and accomplishments.

(b) The President shall transmit to the Congress in January of each year a report, which shall include (1) a comprehensive description of the programed activities and the acomplishments of all agencies of the United States in the field of aeronautics and space activities during the preceding calendar year, and (2) an evaluation of such activities and acomplishments in terms of the attainment of or the failure to attain, the objectives described in section 102(c) of this Act.

(c) Any report made under this section shall contain such recommendations for additional legislation as the Administrator or the President may consider necessary or desirable for the attainment of the objectives described in section 102(c) of this Act.

(d) No information which has been classified for reasons of national security shall be included in any report made under this section, unless such information has been declassified by, or pursuant to authorization given by, the President.

TITLE III—MISCELLANEOUS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Termination. Transfer of functions.

SEC. 301. (a) The National Advisory Committee for Aeronautics, on the effective date of this section, shall cease to exist. On such date all functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records of that organization, shall be transferred to the Administration.

Definitions. 70A Stat. 127.

(b) Section 2302 of title 10 of the United States Code is amended by striking out "or the Executive Secretary of the National Advisory Committee for Aeronautics." and inserting in lieu thereof "or the Administrator of the National Aeronautics and Space Administration."; and section 2303 of such title 10 is amended by striking out "The National Advisory Committee for Aeronautics." and inserting in lieu thereof "The National Aeronautics and Space Administration."

64 Stat. 476. 72 Stat. 432. 72 Stat. 433.

(c) The first section of the Act of August 26, 1950 (5 U.S.C. 22–1), is amended by striking out "the Director, National Advisory Committee for Aeronautics" and inserting in lieu thereof "the Administrator of the National Aeronautics and Space Administration", and by striking out "or National Advisory Committee for Aeronautics" and inserting in lieu thereof "or National Aeronautics and Space Administration".

63 Stat. 936.

(d) The Unitary Wind Tunnel Plan Act of 1949 (50 U.S.C. 511–515) is amended (1) by striking out "The National Advisory Committee for Aeronautics (hereinafter referred to as the 'Committee')" and inserting in lieu thereof "The Administrator of the National Aeronautics and Space Administration (hereinafter referred to as the 'Administrator')"; (2) by striking out "Committee" or "Committee's" wherever they appear and inserting in lieu thereof "Administrator" and "Administrator's", respectively; and (3) by striking out "its" wherever it appears and inserting in lieu thereof "his".

Effective date.

Publication in F.R.

(e) This section shall take effect ninety days after the date of the enactment of this Act, or on any earlier date on which the Administrator shall determine, and announce by proclamation published in the Federal Register, that the Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by this Act.

TRANSFER OF RELATED FUNCTIONS

SEC. 302. (a) Subject to the provisions of this section, the President, for a period of four years after the date of enactment of this Act, may transfer to the Administration any functions (including powers, duties, activities, facilities, and parts of functions) of any other department or agency of the United States, or of any officer or organizational entity thereof, which relate primarily to the functions, powers, and duties of the Administration as prescribed by section 203 of this Act. In connection with any such transfer, the President may, under this section or other applicable authority, provide for appropriate transfers of records, property, civilian personnel, and funds.

Reports to Congress.

(b) Whenever any such transfer is made before January 1, 1959, the President shall transmit to the Speaker of the House of Representatives and the President pro tempore of the Senate a full and complete report concerning the nature and effect of such transfer.

(c) After December 31, 1958, no transfer shall be made under this section until (1) a full and complete report concerning the nature and effect of such proposed transfer has been transmitted by the President to the Congress, and (2) the first period of sixty calendar days of regular session of the Congress following the date of receipt of such report by the Congress has expired without the adoption by the Congress of a concurrent resolution stating that the Congress does not favor such transfer.

ACCESS TO INFORMATION

SEC. 303. Information obtained or developed by the Administrator in the performance of his functions under this Act shall be made available for public inspection, except (A) information authorized or required by Federal statute to be withheld, and (B) information classified to protect the national security: *Provided*, That nothing in this Act shall authorize the withholding of information by the Administrator from the duly authorized committees of the Congress.

SECURITY

SEC. 304. (a) The Administrator shall establish such security requirements, restrictions, and safeguards as he deems necessary in the interest of the national security. The Administrator may arrange with the Civil Service Commission for the conduct of such security or other personnel investigations of the Administration's officers, employees, and consultants, and its contractors and subcontractors and their officers and employees, actual or prospective, as he deems appropriate; and if any such investigation develops any data reflecting that the individual who is the subject thereof is of questionable loyalty the matter shall be referred to the Federal Bureau of Investigation for the conduct of a full field investigation, the results of which shall be furnished to the Administrator.

Requirements.

72 Stat. 433.
72 Stat. 434.

Referral to F.B.I.

(b) The Atomic Energy Commission may authorize any of its employees, or employees of any contractor, prospective contractor, licensee, or prospective licensee of the Atomic Energy Commission or any other person authorized to have access to Restricted Data by the Atomic Energy Commission under subsection 145 b. of the Atomic Energy Act of 1954 (42 U.S.C. 2165(b)), to permit any member, officer, or employee of the Council, or the Administrator, or any officer, employee, member of an advisory committee, contractor, subcontractor, or officer or employee of a contractor or subcontractor of the Administration, to have access to Restricted Data relating to aeronautical and space activities which is required in the performance of his duties and so certified by the Council or the Administrator, as the case may be, but only if (1) the Council or Administrator or designee thereof has determined, in accordance with the established personnel security procedures and standards of the Council or Administration, that permitting such individual to have access to such Restricted Data will not endanger the common defense and security, and (2) the Council or Administrator or designee thereof finds that the established personnel and other security procedures and standards of the Council or Administration are adequate and in reasonable conformity to the standards established by the Atomic Energy Commission under section 145 of the Atomic Energy Act of 1954 (42 U.S.C. 2165). Any individual granted access to such Restricted Data pursuant to this subsection may exchange such Data with any individual who (A) is an officer or employee of the Department of Defense, or any department or agency thereof, or a member of the armed forces, or a contractor or subcontractor of any such department, agency, or armed force, or an officer or employee of any such contractor or subcontractor, and (B) has been authorized to have access to Restricted Data under the provisions of section 143 of the Atomic Energy Act of 1954 (42 U.S.C. 2163).

Access to AEC restricted data.

68 Stat. 942.

68 Stat. 942.

(c) Chapter 37 of title 18 of the United States Code (entitled Espionage and Censorship) is amended by—

(1) adding at the end thereof the following new section:

Espionage and Censorship.
62 Stat. 736-738;
65 Stat. 719.
18 USC 791-798.
Violation.

"§ 799. Violation of regulations of National Aeronautics and Space Administration

"Whoever willfully shall violate, attempt to violate, or conspire to violate any regulation or order promulgated by the Administrator of the National Aeronautics and Space Administration for the protection or security of any laboratory, station, base or other facility, or part thereof, or any aircraft, missile, spacecraft, or similar vehicle, or part thereof, or other property or equipment in the custody of the Administration, or any real or personal property or equipment in the custody of any contractor under any contract with the Administration or any subcontractor of any such contractor, shall be fined not more than $5,000, or imprisoned not more than one year, or both."

Penalty.

(2) adding at the end of the sectional analysis thereof the following new item:

72 Stat. 434.
72 Stat. 435.

"799. Violation of regulations of National Aeronautics and Space Administration."

Protection of U.S. officers and employees.
62 Stat. 756.

(d) Section 1114 of title 18 of the United States Code is amended by inserting immediately before "while engaged in the performance of his official duties" the following: "or any officer or employee of the National Aeronautics and Space Administration directed to guard and protect property of the United States under the administration and control of the National Aeronautics and Space Administration,".

Permission to use firearms.

(e) The Administrator may direct such of the officers and employees of the Administration as he deems necessary in the public interest to carry firearms while in the conduct of their official duties. The Administrator may also authorize such of those employees of the contractors and subcontractors of the Administration engaged in the protection of property owned by the United States and located at facilities owned by or contracted to the United States as he deems necessary in the public interest, to carry firearms while in the conduct of their official duties.

PROPERTY RIGHTS IN INVENTIONS

SEC. 305. (a) Whenever any invention is made in the performance of any work under any contract of the Administration, and the Administrator determines that—

(1) the person who made the invention was employed or assigned to perform research, development, or exploration work and the invention is related to the work he was employed or assigned to perform, or that it was within the scope of his employment duties, whether or not it was made during working hours, or with a contribution by the Government of the use of Government facilities, equipment, materials, allocated funds, information proprietary to the Government, or services of Government employees during working hours; or

(2) the person who made the invention was not employed or assigned to perform research, development, or exploration work, but the invention is nevertheless related to the contract, or to the work or duties he was employed or assigned to perform, and was made during working hours, or with a contribution from the Government of the sort referred to in clause (1),

such invention shall be the exclusive property of the United States, and if such invention is patentable a patent therefor shall be issued to the United States upon application made by the Administrator, unless the Administrator waives all or any part of the rights of the United States to such invention in conformity with the provisions of subsection (f) of this section.

Contract provision.

(b) Each contract entered into by the Administrator with any party for the performance of any work shall contain effective provisions under which such party shall furnish promptly to the Administrator a written report containing full and complete technical information concerning any invention, discovery, improvement, or innovation which may be made in the performance of any such work.

Patent application.

(c) No patent may be issued to any applicant other than the Administrator for any invention which appears to the Commissioner of Patents to have significant utility in the conduct of aeronautical and space activities unless the applicant files with the Commissioner, with the application or within thirty days after request therefor by the Commissioner, a written statement executed under oath setting forth the full facts concerning the circumstances under which such invention was made and stating the relationship (if any) of such invention to the performance of any work under any contract of the Administration. Copies of each such statement and the application to which it relates shall be transmitted forthwith by the Commissioner to the Administrator.

72 Stat. 435.
72 Stat. 436.

Board of Patent Interferences.

(d) Upon any application as to which any such statement has been transmitted to the Administrator, the Commissioner may, if the invention is patentable, issue a patent to the applicant unless the Administrator, within ninety days after receipt of such application and statement, requests that such patent be issued to him on behalf of the United States. If, within such time, the Administrator files such a request with the Commissioner, the Commissioner shall transmit notice thereof to the applicant, and shall issue such patent to the Administrator unless the applicant within thirty days after receipt of such notice requests a hearing before a Board of Patent Interferences on the question whether the Administrator is entitled under this section to receive such patent. The Board may hear and determine, in accordance with rules and procedures established for interference cases, the question so presented, and its determination shall be subject to appeal by the applicant or by the Administrator to the Court of Customs and Patent Appeals in accordance with procedures governing appeals from decisions of the Board of Patent Interferences in other proceedings.

(e) Whenever any patent has been issued to any applicant in conformity with subsection (d), and the Administrator thereafter has reason to believe that the statement filed by the applicant in connection therewith contained any false representation of any material fact, the Administrator within five years after the date or issuance of such patent may file with the Commissioner a request for the transfer to the Administrator of title to such patent on the records of the Commission. Notice of any such request shall be transmitted by the Commissioner to the owner of record of such patent, and title to such patent shall be so transferred to the Administrator unless within thirty days after receipt of such notice such owner of record requests a hearing before a Board of Patent Interferences on the question whether any such false representation was contained in such statement. Such question shall be heard and determined, and determination thereof shall be subject to review, in the manner prescribed by subsection (d) for questions arising thereunder. No request made by the Administrator under this subsection for the transfer of title to any patent, and no prosecution for the violation of any criminal statute, shall be barred by any failure of the Administrator to make a request under subsection (d) for the issuance of such patent to him, or by any notice previously given by the Administrator stating that he had no objection to the issuance of such patent to the applicant therefor.

Waiver.

(f) Under such regulations in conformity with this subsection as the Administrator shall prescribe, he may waive all or any part of the rights of the United States under this section with respect to any invention or class of inventions made or which may be made by any person or class of persons in the performance of any work required by any contract of the Administration if the Administrator determines that the interests of the United States will be served thereby. Any such waiver may be made upon such terms and under such conditions as the Administrator shall determine to be required for the protection of the interests of the United States. Each such waiver made with respect to any invention shall be subject to the reservation by the Administrator of an irrevocable, nonexclusive, nontransferrable, royalty-free license for the practice of such invention throughout the world by or on behalf of the United States or any foreign government pursuant to any treaty or agreement with the United States. Each proposal for any waiver under this subsection shall be referred to an Inventions and Contributions Board which shall be established by the Administrator within the Administration. Such Board shall accord to each interested party an opportunity for hearing, and shall transmit to the Administrator its findings of fact with respect to such proposal and its recommendations for action to be taken with respect thereto.

Inventions and Contributions Board.

License regulations.

72 Stat. 436.
72 Stat. 437.

(g) The Administrator shall determine, and promulgate regulations specifying, the terms and conditions upon which licenses will be granted by the Administration for the practice by any person (other than an agency of the United States) of any invention for which the Administrator holds a patent on behalf of the United States.

Protection of title.

(h) The Administrator is authorized to take all suitable and necessary steps to protect any invention or discovery to which he has title, and to require that contractors or persons who retain title to inventions or discoveries under this section protect the inventions or discoveries to which the Administration has or may acquire a license of use.

Defense agency.
66 Stat. 805-808.

(i) The Administration shall be considered a defense agency of the United States for the purpose of chapter 17 of title 35 of the United States Code.

Definitions.

(j) As used in this section—

(1) the term "person" means any individual, partnership, corporation, association, institution, or other entity;

(2) the term "contract" means any actual or proposed contract, agreement, understanding, or other arrangement, and includes any assignment, substitution of parties, or subcontract executed or entered into thereunder; and

(3) the term "made", when used in relation to any invention, means the conception or first actual reduction to practice of such invention.

CONTRIBUTIONS AWARDS

SEC. 306. (a) Subject to the provisions of this section, the Administrator is authorized, upon his own initiative or upon application of any person, to make a monetary award, in such amount and upon such terms as he shall determine to be warranted, to any person (as defined by section 305) for any scientific or technical contribution to the Administration which is determined by the Administrator to have significant value in the conduct of aeronautical and space activities. Each application made for any such award shall be referred to the Inventions and Contributions Board established under section 305 of this Act. Such Board shall accord to each such applicant an opportunity for hearing upon such application, and shall transmit to the Administrator its recommendation as to the terms of the award, if any, to be made to such applicant for such contribution. In determining the terms and conditions of any award the Administrator shall take into account—

(1) the value of the contribution to the United States;

(2) the aggregate amount of any sums which have been expended by the applicant for the development of such contribution;

(3) the amount of any compensation (other than salary received for services rendered as an officer or employee of the Government) previously received by the applicant for or on account of the use of such contribution by the United States; and

(4) such other factors as the Administrator shall determine to be material.

(b) If more than one applicant under subsection (a) claims an interest in the same contribution, the Administrator shall ascertain and determine the respective interests of such applicants, and shall apportion any award to be made with respect to such contribution among such applicants in such proportions as he shall determine to be equitable. No award may be made under subsection (a) with respect to any contribution—

(1) unless the applicant surrenders, by such means as the Administrator shall determine to be effective, all claims which such applicant may have to receive any compensation (other than the award made under this section) for the use of such contribution or any element thereof at any time by or on behalf of the United States, or by or on behalf of any foreign government pursuant to any treaty or agreement with the United States, within the United States or at any other place;

72 Stat. 437.
72 Stat. 438.

(2) in any amount exceeding $100,000, unless the Administrator has transmitted to the appropriate committees of the Congress a full and complete report concerning the amount and terms of, and the basis for, such proposed award, and thirty calendar days of regular session of the Congress have expired after receipt of such report by such committees.

72 Stat. 438.

APPROPRIATIONS

SEC. 307. (a) There are hereby authorized to be appropriated such sums as may be necessary to carry out this Act, except that nothing in this Act shall authorize the appropriation of any amount for (1) the acquisition or condemnation of any real property, or (2) any other item of a capital nature (such as plant or facility acquisition, construction, or expansion) which exceeds $250,000. Sums appropriated pursuant to this subsection for the construction of facilities, or for research and development activities, shall remain available until expended.

(b) Any funds appropriated for the construction of facilities may be used for emergency repairs of existing facilities when such existing facilities are made inoperative by major breakdown, accident, or other circumstances and such repairs are deemed by the Administrator to be of greater urgency than the construction of new facilities.

Approved July 29, 1958.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D. C.

A PROCLAMATION

1. By virtue of the authority vested in me by the National Aeronautics and Space Act of 1958 (Public Law 85-568, approved July 29, 1958, 72 Stat. 426, 433) I hereby proclaim that as of the close of business September 30, 1958, the National Aeronautics and Space Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by said law

2. In accordance with the provisions of the Act, all functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records of the National Advisory Committee for Aeronautics are hereby transferred to the National Aeronautics and Space Administration.

3. The existing National Advisory Committee for Aeronautics Committees on Aircraft, Missile and Spacecraft Aerodynamics; Aircraft, Missile and Spacecraft Propulsion; Aircraft, Missile and Spacecraft Construction; Aircraft Operating Problems; the Industry Consulting Committee; and the Special Committee on Space Technology and their subcommittees are hereby reconstituted advisory committees to the Administration through December 31, 1958, for the purpose of bringing their current work to an orderly completion.

4. Existing policies, regulations, authorities, and procedural instructions governing the activities of the National Advisory Committee for Aeronautics, not inconsistent with law, and which are applicable to the activities of the National Aeronautics and Space Administration, shall be continued in effect until superseded or revoked.

5. The Langley Aeronautical Laboratory, the Ames Aeronautical Laboratory, and the Lewis Flight Propulsion Laboratory are hereby renamed the Langley Research Center, the Ames Research Center, and the Lewis Research Center, respectively.

DONE at the City of Washington, District of Columbia this 25th day of September in the year Nineteen Hundred and Fifty-Eight.

T. Keith Glennan

T. Keith Glennan
Administrator